DESCRIPTION

INFORMATION PROCESSING METHOD, INFORMATION PROCESSING APPARATUS, AND IMAGE SENSING APPARATUS

5   TECHNICAL FIELD

The present invention relates to a technique of generating an image of a virtual space formed from a virtual object including at least one part.

10   BACKGROUND ART

In a mixed reality system to present, to an observer, a known mixed reality space in which a physical space and a virtual space are blended, a position/orientation measuring device represented by

15   FASTRAK (trademark) available from Polhemus (U.S.A.) is generally used to acquire the viewpoint position and the direction of line of sight in observing the mixed reality space (e.g., U.S. Patent No. 6,522,312).

As an image sensing/display device, an HMD (Head

20   Mounted Display) with a camera is often used. Stereoscopic vision by binocular parallax is also implemented by separately providing left and right image sensing systems and display systems in an HMD.

For the above-described mixed reality system, the

25   present inventor has proposed a technique of laying out CAD data in a virtual space as a virtual object in the virtual space, generating an image obtained by viewing

the virtual object from the viewpoint position and the direction of line of sight, and displaying the image on the display device provided on the HMD. When a virtual object corresponding to virtual CAD data is displayed

5   in a physical space image, the viewpoint can easily and freely be moved. In addition, since the virtual object is composited with the physical space image, the sense of scale for the virtual object can be obtained, and more real display can be executed.

10   On the other hand, a conventional CAD system which uses no mixed reality system has an important function of displaying an assembly tree. Each part in a design target object is selected from an assembly tree and manipulated. When the assembly tree is used,

15   a common operation can be executed at once for a plurality of integrated components.

However, in the mixed reality system, generally, the physical space image is displayed on the display device provided on the HMD. Hence, the display region

20   to display various kinds of information is small. This also results from the small display area of the display device of the HMD.

When stereoscopic vision is implemented by using a stereo HMD, and an assembly tree is carelessly

25   displayed, a sense of discomfort is generated in the stereoscopic vision.

DISCLOSURE OF INVENTION

The present invention has been made in consideration of the above-described problems, and has as its object to provide a technique for, when a

5   virtual object including at least one part and superimposed on a physical space is presented to an observer, displaying information about the parts without damaging the sense of depth with respect to anther image.

10   It is another object of the present invention to provide a technique for, when a virtual object including at least one part and superimposed on a physical space image is presented to an observer, minimizing the problem of images occluded by display of

15   information about the parts.

In order to achieve an object of the present invention, for example, an image processing method of the present invention comprises the following arrangement.

20   That is, an image processing method of generating an image of a virtual space formed from a virtual object including at least one part, characterized by comprising:

a first acquisition step of acquiring a position

25   and orientation of a viewpoint of an observer;

a second acquisition step of acquiring a position and orientation of a pointing device which is worn by

the observer on a hand to execute various kinds of operations;

a layout step of laying out a list image to display a list of pieces of information about the parts

5 near the position acquired in the second acquisition step;

a virtual space image generation step of generating the image of the virtual space after laying out the list image, which is seen in accordance with

10 the position and orientation of the viewpoint; and

an output step of outputting the image generated in the virtual space image generation step to a predetermined display device.

In order to achieve an object of the present

15 invention, for example, an image processing method of the present invention comprises the following arrangement.

That is, an image processing method of generating a virtual image corresponding to a position and

20 orientation of an observer and compositing the virtual image with a physical image corresponding to the position and orientation of the observer, including

acquiring the position and orientation of the observer,

25 generating the virtual image in accordance with the position and orientation of the observer, and

compositing the physical image corresponding to

the position and orientation of the observer with the
virtual image, characterized by comprising:

acquiring a position of pointing means operated
by the observer;

5   identifying a part pointed by the pointing means;

generating a part information virtual image to
display information about the identified part; and

determining a layout position of the part
information virtual image in accordance with the

10   position of the pointing means.

In order to achieve an object of the present
invention, for example, an image processing apparatus
of the present invention comprises the following
arrangement.

15   That is, an image processing apparatus of
generating an image of a virtual space formed from a
virtual object including at least one part,
characterized by comprising:

first acquisition unit adapted to acquire a

20   position and orientation of a viewpoint of an observer;

second acquisition unit adapted to acquire a
position and orientation of a pointing device which is
worn by the observer on a hand to execute various kinds
of operations;

25   layout unit adapted to lay out a list image to
display a list of pieces of information about the parts
near the position acquired by the second acquisition

unit;

virtual space image generation unit adapted to generate the image of the virtual space after laying out the list image, which is seen in accordance with

5   the position and orientation of the viewpoint; and

output unit adapted to output the image generated by the virtual space image generation unit to a predetermined display device.

In order to achieve an object of the present

10   invention, for example, an image processing apparatus of the present invention comprises the following arrangement.

That is, an image processing apparatus of generating a virtual image corresponding to a position

15   and orientation of an observer and compositing the virtual image with a physical image corresponding to the position and orientation of the observer, comprising:

acquiring unit adapted to acquire the position

20   and orientation of the observer,

generating unit adapted to generate the virtual image in accordance with the position and orientation of the observer, and

compositing unit adapted to composite the

25   physical image corresponding to the position and orientation of the observer with the virtual image, characterized by comprising:

acquiring unit adapted to acquire a position of pointing means operated by the observer;

identifying unit adapted to identify a part pointed by the pointing means;

5   generating unit adapted to generate a part information virtual image to display information about the identified part; and

determining unit adapted to determining a layout position of the part information virtual image in

10   accordance with the position of the pointing means.

Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate

15   the same or similar parts throughout the figures thereof.

BRIEF DESCRIPTION OF DRAWINGS

The accompanying drawings, which are incorporated

20   in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

Fig. 1 is a view showing the outer appearance of

25   a system according to the first embodiment of the present invention;

Fig. 2 is a view showing the schematic

arrangement of an HMD 110 according to the first

embodiment of the present invention;

Fig. 3 is a view showing the structure of a

stylus 120;

5   Fig. 4 is a flowchart of processing (main thread)

of causing a CPU 3101 to generate the mixed reality

space image and output it to the display screen of the

HMD 110 according to the first embodiment of the

present invention;

10   Fig. 5 is a view showing an example of the mixed

reality space image;

Fig. 6 is a view showing an example of an image

(list image) in which when a console portion 500 of a

virtual object 170 of a copying machine is pointed by

15 the stylus 120, pieces of information about the parts

included in the console portion 500 are listed in a

tree form (assembly tree);

Fig. 7 is a view showing a display example of the

mixed reality space image when the list image is laid

20 out and displayed;

Fig. 8 is a view showing a display example of a

list image 801 having a completely transparent

background and opaque characters;

Fig. 9 is a view showing a display example of the

25 mixed reality space image when the list image is laid

out and displayed;

Fig. 10 is a view for explaining a region where

no virtual object is displayed;

Fig. 11 is a view showing an example of an image which is displayed on the display screen of the HMD 110 when the position and orientation of the viewpoint of

5 an observer 100 are moved;

Fig. 12 is a view showing a display example of the list image which is laid out without overlapping the display region of the virtual object 170;

Fig. 13 is a view showing the assembly tree of

10 parts included in a virtual object A;

Fig. 14 is a view showing a list image preferentially rendered for a hand region;

Fig. 15 is a view showing a display example of the mixed reality space image obtained by adjusting

15 display of the list image;

Fig. 16 is a flowchart of processing of masking the hand region in a physical space image (real image);

Fig. 17 is a flowchart of processing of switching between the list image and the hand region to

20 preferentially display one of them by referring to a flag;

Fig. 18 is a flowchart of processing of switching between the list image and the hand region to preferentially display one of them;

25 Fig. 19 is a flowchart of list image display processing according to the second embodiment of the present invention, which is executed in step S404;

Fig. 20 is a flowchart of list image display processing according to the third embodiment of the present invention, which is executed in step S404;

Fig. 21 is a flowchart of processing to be executed by the CPU 3101 when an operation is executed for the assembly tree displayed in the list image;

Fig. 22 is a flowchart showing details of processing in step S2122;

Fig. 23 is a flowchart of processing of determining on the basis of the distance between the position of the stylus 120 and the virtual object up to which layer level in the parent/child structure of the parts included in the virtual object is to be presented by the list image;

Fig. 24 is a view showing a display example of the list image which is displayed when the stylus 120 is moved close to the virtual object 170 of the copying machine;

Fig. 25 is a view showing a display example of the list image when the stylus 120 is further moved close to the console module 500;

Fig. 26 is a view showing a display example of the list image of a portion pointed by gesture;

Fig. 27 is a view showing a display example in which when a planar virtual object 2711 with a description "upper paper cassette" is pointed by the position of the stylus 120 in a list image 2701, a

corresponding part 2712 in the virtual object 170 of the copying machine blinks;

Fig. 28 is a flowchart of processing of displaying the list image of a portion pointed by gesture;

Fig. 29 is a view for explaining an operation of designating a position in the depth direction as indicated by a dotted line to more specifically designate a target node;

Fig. 30 is a flowchart of processing related to display of the hand region and list image; and

Fig. 31 is a block diagram showing the basic arrangement of a computer 140.

BEST MODE FOR CARRYING OUT THE INVENTION

Preferred embodiments of the present invention will now be described in detail in accordance with the accompanying drawings.

[First Embodiment]

In this embodiment, when the image of a virtual space formed from a virtual object including at least one part is superimposed on the image of the physical space and presented to the observer, pieces of information about the parts are also presented to the observer. A system to execute such presentation will be described below.

Fig. 1 is a view showing the outer appearance of

the system according to this embodiment.

Referring to Fig. 1, reference numeral 100 denotes an observer. He/she wears an HMD (Head Mounted Display) 110 (to be described later) on the head and a

5   stylus (pointing device) 120 (to be described later) in the hand ("wear" means both "hold in hand" and "attached to hand").

A position/orientation sensor transmitter 130 generates a magnetic field. A position/orientation

10 sensor receiver 121 provided in the stylus 120 and a position/orientation sensor receiver 113 provided on the HMD 110 measure the magnetic field intensities corresponding to their positions and orientations.

A position/orientation sensor main body 131

15 controls the position/orientation sensor transmitter 130. The position/orientation sensor main body 131 also receives signals representing magnetic field intensities measured by the position/orientation sensor receivers 121 an 113 and obtains the position and

20 orientation of each sensor receiver in the sensor coordinate system (coordinate system in which the origin is set at the position of the position/orientation sensor transmitter 130, and the three axes crossing each other perpendicularly at the

25 origin are set as X-, Y-, and Z-axes) in accordance with the magnetic field intensity represented by the received signal. Data representing the obtained

position and orientation is output to a computer 140 of
the subsequent stage. As the sensor system, for
example, FASTRAK (registered trademark) available from
Polhemus (U.S.A.) can be used.

5   A virtual object 170 includes at least one part.
The virtual object 170 in Fig. 1 is a copying machine.
However, the present invention is not limited to this
and can be applied to any other virtual object
including at least one part. The virtual object 170 is
10   illustrated in Fig. 1 for the descriptive convenience.
Actually, only the observer 100 or the operator who is
looking at the display screen of the computer 140 can
see the virtual object. Reference numeral 180 denotes
a physical object 180. The computer 140 executes data
15   communication with an external device through a network
line 150. The network line 150 is formed from a cable
in Fig. 1. However, a wireless network can also be
used.

The computer 140 obtains the position and
20   orientation of the viewpoint of the observer 100 by
executing processing (to be described later) on the
basis of data from the position/orientation sensor main
body 131. The computer 140 generates a virtual space
image (virtual object image) which can be seen in
25   accordance with the position and orientation of the
viewpoint of the observer 100. The virtual space image
includes a list image to display a list of information

about parts included in the virtual object. The list

image will be described later. The computer 140

executes processing of superimposing the generated

virtual space image on the physical space image

5   obtained from the HMD 110 and outputting the

superimposed image onto the display screen of the HMD

110.

Fig. 2 is a view showing the schematic

arrangement of the HMD 110 according to this

10 embodiment. As shown in Fig. 2, the HMD 110 includes a

video camera 111, LCD 112, position/orientation sensor

receiver 113, and optical prisms 114 and 115.

The video camera 111 senses light guided by the

optical prism 115. As a result, the physical space

15 seen in accordance with the position and orientation of

the viewpoint of the observer is sensed. In this

embodiment, a single video camera 111 is provided in

the HMD 110. However, the present invention is not

limited to this. To sense the physical space image

20 seen in accordance with the position and orientation of

each of the right and left eyes of the observer, two

video cameras may be provided. The obtained image

signal is output to the computer 140.

The position/orientation sensor receiver 113

25 measures the position and orientation of its own in the

sensor coordinate system, as described above.

Actually, the position/orientation sensor receiver 113

measures the magnetic field intensity corresponding to the position and orientation of its own. The position/orientation sensor main body 131 obtains the position and orientation of the position/orientation

5 sensor receiver 113 in the sensor coordinate system on the basis of the measured intensity. Data representing the obtained position and orientation is output to the computer 140 of the subsequent stage. The position and orientation of the viewpoint of the observer 100 in the

10 sensor coordinate system can be obtained by processing (to be described later) by the computer 140.

The LCD 112 receives the image signal generated by and output from the computer 140 and displays an image based on the received image signal. In this

15 embodiment, an image (mixed reality space image) obtained by superimposing the virtual space image generated by the computer 140 on the physical space image sensed by the video camera 111 is displayed. The displayed image is guided to the pupil of the observer

20 by the optical prism 114.

Fig. 3 is a view showing the structure of the stylus 120. As shown in Fig. 3, the stylus 120 comprises the position/orientation sensor receiver 121 and a stylus button 122. The position/orientation

25 sensor receiver 121 measures the position and orientation of its own in the sensor coordinate system, as described above. Actually, the position/orientation

sensor receiver 121 measures the magnetic field intensity corresponding to the position and orientation of its own. The position/orientation sensor main body 131 obtains the position and orientation of the

5   position/orientation sensor receiver 121 in the sensor coordinate system on the basis of the measured intensity. Data representing the obtained position and orientation is output to the computer 140 of the subsequent stage. In this embodiment, the position and

10   orientation of the position/orientation sensor receiver 121 are handled as the position and orientation of the stylus 120. However, the present invention is not limited to this.

The stylus button 122 can be set in the ON/OFF

15   state by the operation of the observer 100. A signal representing each state is output to the computer 140 of the subsequent stage.

Fig. 31 is a block diagram showing the basic arrangement of the computer 140.

20   A CPU 3101 controls the entire computer 140 by using a program or data stored in a RAM 3102 or ROM 3103. The CPU 3101 also executes processing (to be described later).

The RAM 3102 has an area to temporarily store a

25   program or data loaded from an external storage device 3106 and also a work area used by the CPU 3101 to execute various kinds of processing. The RAM 3102 also

has an area to temporarily store data (e.g., data
representing the position and orientation of the
position/orientation sensor receiver in the sensor
coordinate system, which is received from the

5   position/orientation sensor main body 131, or physical
space image data received from the video camera 111 of
the HMD 110) received from an external device through
an I/F 3107.

The ROM 3103 stores the boot program and data

10 about setting of the computer 140.

An operation unit 3104 includes a keyboard and
mouse and is used by the operator to input various
kinds of instructions to the CPU 3101.

A display unit 3105 includes a CRT or liquid

15 crystal panel and displays an image to be displayed on
the display screen (LCD 112 in Fig. 2) of the HMD 110
or GUI to be used by the operator to execute various
kinds of operations.

The external storage device 3106 is a mass

20 storage device such as a hard disk drive. The external
storage device 3106 stores a program or data to make
the OS (Operating System) or CPU 3101 execute each
processing to be described later. Some or all of the
programs and data are loaded to the RAM 3102 under the

25 control of the CPU 3101 and processed by the CPU 3101.
Data stored in the external storage device 3106
includes a data group to generate a list image (to be

described later) and data to generate an image of each
virtual object (virtual object of copying machine in
Fig. 1) which forms the virtual space. Information
about each part included in the virtual object is held

5   in association with data to generate the image of the
part. Known data (information) in the following
description is also stored in the external storage
device 3106 and loaded to the RAM 3102 for use.

The I/F 3107 connects the computer 140 to an

10   external device. The HMD 110, position/orientation
sensor main body 131, and network line 150 can be
connected to the I/F 3107. The I/F 3107 is simplified
in Fig. 31 for the descriptive convenience. Actually,
preferably, a plurality of I/Fs are provided in

15   accordance with devices to be connected, and a target
corresponding to each I/F is connected.

A bus 3108 connects the above-described units.

Processing of causing the computer 140 having the
above-described arrangement to display a mixed reality

20   space image on the display screen of the HMD 110 will
be described next.

The video camera 111 provided in the HMD 110
always senses the image (moving image) of the physical
space seen in accordance with the position and

25   orientation of the HMD 110. The image of each sensed
frame is sequentially output to the computer 140.

The position/orientation sensor transmitter 130

generates a magnetic field under the control of the position/orientation sensor main body 131. The position/orientation sensor receiver 113 of the HMD 110 and the position/orientation sensor receiver 121

5   measure the magnetic field intensities corresponding to their positions and orientations. Signals representing the measured intensities are output to the position/orientation sensor main body 131. The position/orientation sensor main body 131 obtains the

10 position and orientation of each sensor receiver in the sensor coordinate system on the basis of the received signal. That is, the position and orientation of each sensor receiver in the sensor coordinate system are determined in accordance with the magnetic field

15 intensity measured by the sensor receiver. The position/orientation sensor main body 131 outputs data representing the obtained positions and orientations to the computer 140.

Data of the physical space image from the HMD 110

20 and data representing the positions and orientations of the sensor receivers in the sensor coordinate system from the position/orientation sensor main body 131 are input to the RAM 3102 of the computer 140 through the I/F 3107.

25   The CPU 3101 converts the data representing the position and orientation of the position/orientation sensor receiver 113 in the sensor coordinate system

into data representing the position and orientation of the video camera 111 in the sensor coordinate system by using offset data (data representing the position/orientation relationship between the

5   position/orientation sensor receiver 113 and the video camera 111, which is measured in advance) loaded from the external storage device 3106 to the RAM 3102 in advance. The position and orientation of the video camera 111 in the sensor coordinate system will be

10   handled as the position and orientation of the viewpoint of the observer 100 hereinafter.

The CPU 3101 lays out the virtual object 170 in the virtual space. The layout position and orientation are determined in advance by known data. The virtual

15   object 170 includes at least one part, as described above. When the respective parts are laid out at predetermined positions and orientations, the virtual object 170 can be laid out in the virtual space. Processing of laying out a virtual object including at

20   least one part in a virtual space is known, and a description thereof will be omitted.

The coordinate system in the virtual space shares the "origin and three axes" with the sensor coordinate system. That is, the sensor coordinate system matches

25   the coordinate system of the virtual space. Hence, the CPU 3101 can generate the image of the virtual space seen from the position and orientation of the viewpoint

of the observer 100 by using the data of the position
and orientation of the viewpoint of the observer 100
and the data of the virtual space loaded from the
external storage device 3106 to the RAM 3102 in

5   advance.

The data of the virtual space is data about each
virtual object which forms the virtual space. Data
about a virtual object is data about each part included
in the virtual object, including part shape data,

10 texture data, and data representing the position and
orientation. Data about a list image is also included
in the data of the virtual space. Use of this data
will be described later.

Processing of generating the image of the virtual

15 space seen from predetermined position and orientation
is known, and a description thereof will be omitted.

The generated virtual space image is superimposed
on the physical space image stored in the RAM 3102 in
advance. The superimposed image is output onto the

20 display screen of the HMD 110 through the I/F 3107 as
the mixed reality space image.

Fig. 5 is a view showing an example of the mixed
reality space image. The image shown in Fig. 5
includes the virtual object 170 of the copying machine

25 in Fig. 1 and the stylus 120 as a physical object. In
this embodiment, information about each part included
in the copying machine is displayed together with the

image.

For example, the operator moves the stylus 120 to
one of the parts included in the virtual object 170 and
presses the stylus button 122. A signal representing
5   that the button is pressed is transmitted to the CPU
3101 through the I/F 3107. The CPU 3101 refers to data
representing the position and orientation of the
position/orientation sensor receiver 121 in the sensor
coordinate system, which is stored in the RAM 3102, and
10   specifies the part closest to the position. The data
of the virtual object contains the position data of
each part. By referring to this data, the part closest
to the position of the stylus 120 is specified. If no
part is present within a predetermined distance range
15   from the position of the position/orientation sensor
receiver 121, a signal representing that no part can be
specified is sent to processing of the subsequent
stage.

Fig. 6 is a view showing an example of an image
20   (list image) in which when a console portion 500 of the
virtual object 170 of the copying machine is pointed by
the stylus 120, pieces of information about the parts
included in the console portion 500 are listed in a
tree form (assembly tree).

25   When the part closest to the stylus 120 is
specified, and information about this part, which is
associated with the specified part, is to be displayed,

information about only the part can be displayed.
Alternatively, since the parts included in the virtual
object are generally managed in a parent-child
structure (hierarchical structure) on the basis of the

5 position/orientation relationship between the parts,
information about all or some of parts corresponding to
the children of the specified part may be displayed.
The list image is laid out in the virtual space so that
the information description plane can be seen from the

10 position and orientation of the viewpoint of the
observer 100. When the part closest to the
position/orientation sensor receiver 121 cannot be
specified (if no part is present within a predetermined
distance range from the position of the

15 position/orientation sensor receiver 121), the list
image is not displayed.

Displayed information contains the material names
and texture names of the parts (parts corresponding to
the children of the console portion 500: liquid crystal

20 display panel, online button, discharge button, up
button, down button, right button, and left button in
Fig. 6) included in the console portion 500 in Fig. 6.
However, the present invention is not limited to this,
and any other information may be displayed. As

25 described above, information about each part is
contained in the data of the virtual space in
association with data necessary for generating the

image of the part. For this reason, when the part pointed by the stylus 120 is specified, information about this part in the data of the virtual space can be referred to. Hence, the information to be described in

5   the list image can be obtained.

The list image is displayed on the display screen of the HMD 110. The operator can refer to the information about the part pointed by the stylus 120 by referring to information of the list image. When the

10   number of pieces of displayed information increases, the area of the list image also increases. Then, the virtual object 170 or physical space image is hard to see. In stereoscopic vision, when the list image three-dimensionally overlaps other virtual and physical

15   objects, a sense of discomfort is generated in the stereoscopic vision.

In this embodiment, the list image is laid out near the stylus 120 in the virtual space and closer to the position of the viewpoint of the observer 100 than

20   the stylus 120.

Fig. 7 is a view showing a display example of the mixed reality space image when the list image is laid out and displayed in the above-described way. Referring to Fig. 7, the list image is displayed in a

25   semitransparent form and does not hinder the operator from seeing other images. Various techniques can be used to display an image in a semitransparent form.

For example, a technique of controlling the α value of each pixel of the image can be used. These techniques are known, and a description thereof will be omitted.

In laying out the list image, for example, the
5   list image is laid out at a position that internally divides the line segment connecting the position of the viewpoint of the observer 100 and the position of the stylus 120 to t : (1-t) such that the information description plane is seen from the position and
10   orientation of the viewpoint of the observer 100. The orientation of the list image is set, e.g., the same as the orientation of the viewpoint of the observer. In this way, the position and orientation of layout of the list image are obtained by using the position and
15   orientation of the observer and the position of the stylus.

As the value t, a value close to 1 as much as possible is preferably set such that the list image is located near the position of the stylus 120. After
20   laying out the list image in the virtual space, the CPU 3101 generates, as a virtual space image, an image in which the virtual space including the virtual object and list image is seen in accordance with the position and orientation of the viewpoint of the observer 100.

25   When the list image is displayed in the above manner, the list image (assembly tree) is not occluded by another image practically. In addition, the list

image is displayed at almost the same depth as the stylus 120 held in the hand. Hence, even in stereoscopic vision, no sense of discomfort is generated in the stereoscopic vision by binocular

5   parallax by an extreme difference in the stereoscopic vision.

Fig. 4 is a flowchart of processing (main thread) of causing the CPU 3101 to generate the mixed reality space image and output it to the display screen of the

10   HMD 110 according to this embodiment. The program to cause the CPU 3101 to execute processing according to the flowchart in Fig. 4 is stored in the external storage device 3106. The program is loaded to the RAM 3102 under the control of the CPU 3101 and executed by

15   the CPU 3101. Known data in the above description is loaded from the external storage device 3106 to the RAM 3102 in advance.

The CPU 3101 activates the position/orientation thread (step S401) and image capture thread (step

20   S402). A thread indicates a series of programs parallelly processed in the computer 140. Hence, information of, e.g., the operation mode is shared by the main thread and all threads.

In the position/orientation thread, the positions

25   and orientations of the position/orientation sensor receivers 113 and 121 in the sensor coordinate system, which are received from the position/orientation sensor

receivers 113 and 121 through the position/orientation
sensor main body 131 and I/F 3107, are acquired (step
S410). The CPU 3101 obtains the position and
orientation of the viewpoint of the observer 100 in the
5   sensor coordinate system by using the offset data and
data representing the position and orientation of the
position/orientation sensor receiver 113 in the sensor
coordinate system and stores the data of the obtained
position and orientation in the RAM 3102 (step S403).
10   If data representing the position and orientation of
the viewpoint of the observer 100 is already stored in
the RAM 3102, the data is overwritten and updated.

The CPU 3101 also stores, in the RAM 3102, data
representing the position and orientation of the
15   position/orientation sensor receiver 121 in the sensor
coordinate system (step S403). If data representing
the position and orientation of the
position/orientation sensor receiver 121 in the sensor
coordinate system is already stored in the RAM 3102,
20   the data is overwritten and updated.

Next the virtual space is updated (step S404).
More specifically, when the virtual space changes its
position, orientation, and color along with the elapse
of time, the data of the position, orientation, and
25   color are updated. In this embodiment, in step S404,
the part closest to the position (i.e., the position of
the position/orientation sensor receiver 121 in the

sensor coordinate system) of the stylus 120 is
specified. Only when the part is specified,
information about the specified part is specified from
the data of the virtual space.

5   In the example shown in Fig. 5, the stylus 120 is
moved to the position of the console portion 500 of the
virtual object 170 of the copying machine, and the
stylus button 122 is pressed there. The CPU 3101
compares the position of the position/orientation

10   sensor receiver 121 at this time with the position of
each part included in the virtual object 170 of the
copying machine to specify the part, i.e., console
portion 500 closest to the position/orientation sensor
receiver 121. The CPU 3101 specifies information about

15   all parts corresponding to the children of the console
portion 500 from the data of the virtual object 170 of
the copying machine.

       When the pieces of information about the parts
are obtained, the list image shown in Fig. 6, in which

20   the pieces of information are described, is generated.
An example of this image will be described below.

       A polygon is prepared for each information to be
displayed. A texture which expresses information about
one part by a character string image (created and

25   stored in the external storage device 3106 in advance)
is mapped to the polygon, thereby generating a planar
virtual object with the description of information

about the part. A planar virtual object is created for
each part, and a list image (list image is also a
planar virtual object) is created by connecting the
planar virtual objects of the respective parts. Which

5   polygon has information about which part is managed.

A thus generated list image is laid out at the
position that internally divides the line segment
connecting the position of the position/orientation
sensor receiver 121 and the position of the viewpoint

10 of the observer 100 to t : (1-t) such that the
information description plane is seen from the position
and orientation of the viewpoint of the observer 100.

That is, in step S404, the virtual object 170 and
list image are laid out in the virtual space.

15   In the image capture thread, the physical space
image obtained from the video camera 111 of the HMD 110
is acquired (step S420). The image is stored in a
predetermined area of the RAM 3102 (step S405).

The virtual space updated in step S404, i.e., the

20 virtual space image in which the virtual object 170 and
list image laid out in step S404 are viewed from the
position and orientation of the viewpoint of the
observer 100 is superimposed on the physical space
image stored in the predetermined area of the RAM 3102

25 in step S405 and rendered (step S406).

The image of a mixed reality space obtained by
superimposing the virtual space image on the physical

space image is generated in the predetermined area.
The CPU 3101 outputs the obtained mixed reality space
image to the display screen of the HMD 110 through the
I/F 3107 (step S407). The mixed reality space image

5   may be output to the display device 3105 and presented
to the operator.

It is determined whether an instruction to end
this processing is input through the operation unit
3104. If NO in step S408, the processing returns to

10   step S403. If YES in step S408, the processing is
ended.

Fig. 9 is a view showing a display example of the
mixed reality space image when the list image is laid
out and displayed by the above processing.

15   As described above, according to this embodiment,
information about each part included in the virtual
object can be displayed without damaging the sense of
depth with respect to anther image.

In this embodiment, the HMD 110 is of video

20   see-through type. However, an HMD of optical
see-through type may be used. In this case, the video
camera 111 is unnecessary, and processing of inputting
the physical space image is also unnecessary. Hence,
the CPU 3101 executes processing without steps S402,

25   S405, S420, and S407 in the flowchart shown in Fig. 4.

In this embodiment, to display the list image on
the display screen of the HMD 110, the list image is

laid out at the position that internally divides the line segment connecting the position of the position/orientation sensor receiver 121 and the position of the viewpoint of the observer 100 in the

5 virtual space. That is, in this embodiment, the list image is handled as a 3D virtual object. However, the present invention is not limited to this, and the list image may be handled as a 2D image. In this case, the position of the position/orientation sensor receiver

10 121 may be projected onto a projection plane to display the image on the display screen of the HMD 110, and the list image may be displayed at (or near) the projection position. In displaying the list image, the virtual space image except the list image is superimposed on

15 the physical space image, and the list image is displayed on the mixed reality space image in accordance with the flowchart shown in Fig. 4.

The list image may be displayed as a 3D virtual object in the display screen of the HMD 110 and as a 2D

20 image in the display screen of the display device 3105 of the computer 140.

To project the image, a known projection conversion matrix to display an object in a virtual space onto a display screen is used. At this time, the

25 list image may be a window in which pieces of information about parts are listed as a text.

[Second Embodiment]

In this embodiment, the display position of a
list image is changed, and display is turned on/off in
addition to the first embodiment. The main thread of
the second embodiment is the same as in the first

5   embodiment (according to the flowchart shown in Fig. 4)
except list image display processing in step S404.

Fig. 19 is a flowchart of list image display
processing according to this embodiment, which is
executed in step S404. Processing according to the

10   flowchart shown in Fig. 19 is executed after the
virtual object image is generated.

It is determined whether a mode to display a list
image (assembly tree) is set (step S1901). This mode
can be set by an operation unit 3104. Data

15   representing the set mode is stored in a RAM 3102.
Hence, in step S1901, it is determined by referring to
this data whether the display mode or non-display mode
is set. There are also various kinds of modes which
can be set by the operation unit 3104, and data

20   representing the set mode is stored in the RAM 3102.
Hence, in determining a mode, it is determined by
referring to the data whether the mode is set.

If the non-display mode is set, the processing
advances to step S1902 to end the processing while

25   keeping the list image in the non-display mode. In the
non-display mode, layout of the list image is actually
omitted. Alternatively, the list image is moved

outside the display screen of an HMD 110 in the virtual space.

If the display mode is set, the processing advances to step S1911 to determine whether a fixed

5   mode is set to display the list image at a fixed position on the display screen of the HMD 110 (sep S1911).

If YES in step S1911, i.e., the list image is to be displayed at a fixed position on the display screen

10   of the HMD 110, the processing advances to step S1912 to display the list image at a predetermined position on the display screen of the HMD 110 (step S1912).

More specifically, the list image is laid out near a position spaced apart from the position of the

15   viewpoint of an observer 100 in the direction of the line-of-sight vector (vector with an infinite length from the position of the viewpoint of the observer 100 to the direction defined by the orientation of the viewpoint) by a predetermined distance.

20   Fig. 11 is a view showing an example of an image which is displayed on the display screen of the HMD 110 when the position and orientation of the viewpoint of the observer 100 are moved. Referring to Fig. 11, reference numeral 1001 denotes a display screen. As

25   shown in Fig. 11, even when the position and orientation of the viewpoint of the observer 100 move to see an object except a virtual object 170, the

display position of a list image 701 does not change according to the processing in step S1912.

If NO in step S1911, the processing advances to step S1921 to determine whether a mode to display the list image outside the display region of the virtual object on the display screen of the HMD 110 is set (step S1921). If NO in step S1921, the processing advances to step S1922 to execute processing of laying out the list image near the position of a stylus 120, as in the first embodiment (step S1922).

If YES in step S1921, the processing advances to step S1923 to specify the display region of the virtual object on the display screen of the HMD 110 (step S1923). A region except the region specified in step S1923 is specified on the display screen of the HMD 110 (step S1924). For example, in the display screen shown in Fig. 10, the right region is the region where no virtual object is displayed.

The list image is laid out in the virtual space such that the list image is displayed at an appropriate position (e.g., position at which the overlap region between the list image and the display region of the virtual object is minimized) in the region specified in step S1924, i.e., in the region except the display region of the virtual object on the display screen of the HMD 110 (step S1925). For example, the projection position at the appropriate position in the virtual

space on the display screen of the HMD 110 is obtained by executing back projection conversion for the appropriate position, and the list image is laid out at (or near) the obtained position. As a result, as shown in Fig. 12, the list image can be laid out without overlapping the display region of the virtual object 170.

As an example of the detailed processing in steps S1923 to S1925, the rendering range of the virtual object on the display screen is calculated by using a matrix (known matrix used for display) to project the virtual object on the display screen. A position on a plane perpendicular to the nearest line of sight outside the calculated range is calculated as the display position of the list image. As another example, the direction from the position of line of sight (position of HMD 110) to the central point of the virtual object and the angle from the direction to center, at which the virtual object overlaps the list image, are calculated, and the nearest position outside the angle is calculated as the display position of the list image.

In displaying the list image in stereoscopic vision, stereoscopic perception can be difficult depending on the display depth. When the list image is displayed in a region which does not overlap the virtual object, display easy to see without sense of

discomfort can be implemented by locating the list
image at a depth in the same range as display of the
virtual object.

Referring back to Fig. 19, it is determined next
5   whether a mode to place the list image in the display
screen of the HMD 110 is set (step S1931). If YES in
step S1931, the processing advances to step S1932 to
check whether the list image laid out at the layout
position determined in step S1925 projects from the
10 display screen of the HMD 110 (step S1932). This check
is done by checking, e.g., whether when the coordinate
values of the four corners of the list image in the
virtual space are projected in the display screen of
the HMD 110, the values are placed in the display
15 screen.

If the list image projects from the display
screen, the processing advances to step S1933 to move
the layout position of the list image in the virtual
space such that the coordinate values of the four
20 corners of the list image are placed in the display
screen of the HMD 110 (step S1933).

With the above-described function, even when the
operator is unskilled in operating the stylus or
system, the assembly tree can properly be displayed.
25 [Third Embodiment]

In this embodiment, a function of making the list
image displayed in the first embodiment semitransparent

is added.

Fig. 8 is a view showing a display example of a
list image 801 having a completely transparent
background and opaque characters. The characters may

5   be hard to read depending on the background. However,
when the list image shown in Fig. 8 is employed, images
other than the list image are easier to see than the
example shown in Fig. 7.

Fig. 20 is a flowchart of list image display

10   processing according to this embodiment, which is
executed in step S404. In this embodiment, the list
image is a 3D virtual object, as in the first
embodiment. However, it may be a 2D image, as in the
second embodiment.

15   When a virtual object is present in the direction
of line of sight of an observer 100, it is determined
whether a mode to display a semitransparent list image
is set (step S2010). This mode can be set by an
operation unit 3104. Data representing the set mode is

20   stored in a RAM 3102. Hence, in step S2010, it is
determined by referring to this data whether the
semitransparent display mode or non-semitransparent
display mode is set. There are also various kinds of
modes which can be set by the operation unit 3104, and

25   data representing the set mode is stored in the RAM
3102. Hence, in determining a mode, it is determined
by referring to the data whether the mode is set.

If the non-semitransparent display mode is set,
the processing advances to step S2022 to generate a
polygon having a non-transparent color by controlling
the α value of the polygon. Processing of mapping a
texture which describes information about the part to
the polygon is executed for each part (step S2022).
That is, the list image is generated, as in the first
embodiment. This processing also applies to a 2D list
image. The list image is generated, as in the first
embodiment.

If semitransparent display is to be executed, the
processing advances to step S2012 to obtain the angle
made by a line segment A from the position of the
viewpoint of the observer 100 to the position of the
virtual object (e.g., the barycenter of all parts
included in the virtual object) and a line-of-sight
vector B (vector with an infinite length from the
position of the viewpoint to the direction defined by
the orientation) (step S2012). When the obtained angle
has a predetermined value or less (value close to 0 is
preferable), it can be determined that the virtual
object is present in the direction of line of sight of
the observer 100. The processing advances to step
S2021 to generate a polygon having a transparent color
by controlling the α value of the polygon. Processing
of mapping a texture which describes information about
the part to the polygon is executed for each part,

thereby generating the list image (step S2021). This
texture is created in advance as transparent except the
character portion (the α values of pixels included in
portions except the character portion are set

5   transparent). The transparency of the polygon is
higher than the polygon in step S2022.

This processing also applies to a 2D list image.
Pixels included in portions except the character
portion are set transparent by controlling the α values

10   of the pixels except the character portion.

When the virtual object is present in the
direction of line of sight of the observer, i.e., when
it is assumed that the observer is gazing at the
virtual object, gaze of the virtual object can be

15   hindered by display of the list image. To prevent
this, in this embodiment, when it is determined that
the virtual object is present in the direction of line
of sight of the observer, the list image with higher
transparency is displayed. In this case, information

20   to be presented by the list image can be shown to the
observer without hindering gaze of the virtual object.

If the angle obtained in step S2012 has a
predetermined value or more, the processing advances to
step S2022.

25   Processing in step S2012 or S2020 can employ any
method if the purpose of checking whether a virtual
object is present in the direction of line of sight can

be achieved. More specifically, in this embodiment, the angle made by the line-of-sight vector B and the line segment A from the position of the viewpoint of the observer 100 to the position of the virtual object

5   (e.g., the barycentric positions of all parts included in the virtual object) is obtained. When the angle has a predetermined value or less, it is determined that the virtual object is present in the direction of line of sight. Except this, when the virtual object is

10   formed from a polygon, crossing between the line-of-sight vector and the polygon is determined. It can be determined that the virtual object is present in the direction of line of sight when an intersection is present. As described above, the method is not

15   particularly limited.

The list image generated by the above processing is displayed on the display screen of the HMD 110 or a display device 3105.

[Fourth Embodiment]

20   In this embodiment, the operation for the assembly tree displayed in the list image and the display range in the above embodiments are controlled. The operation for the assembly tree is executed by using a stylus 120 an observer 100 wears in the hand.

25   Hence, the list image must be displayed at a fixed position without following the position of the stylus 120.

Fig. 21 is a flowchart of processing to be
executed by a CPU 3101 when the operation is executed
for the assembly tree displayed in the list image.
Processing according to the flowchart shown in Fig. 21
5   is executed after all processing operations in step
S404 are ended.

The operator of a computer 140 looks at a list
image displayed on the display screen of a display
device 3105. If the observer 100 is going to do some
10   operation for displayed information about the
respective parts, the operator executes a predetermined
operation (e.g., pressing or clicking on a
predetermined button) by using the mouse or keyboard
included in an operation unit 3104 to change the mode
15   to permit the operation.

When such operation input is done, the
instruction by the operation is sent to a CPU 3101.
The CPU 3101 always receives the instruction (step
S2101). When the operation instruction is input, i.e.,
20   when the CPU 3101 detects the instruction (step S2111),
the processing advances to step S2112 to set a mode to
permit the operation (step S2112). Actually, data
representing this mode is stored in a RAM 3102. Upon
detecting the instruction, the CPU 3101 sets a value
25   representing the "mode to permit the operation" to the
data, thereby setting the mode to permit the operation.

The CPU 3101 checks by referring to the data

representing the mode whether the mode (assembly tree operation mode) to permit the operation is set (step S2121). If YES in step S2121, the processing advances to step S2122 to execute processing to be described

5   later. If a mode (normal mode) not to permit the operation is set, the processing advances to step S2123 to execute the same processing as in the first embodiment. That is, in the normal mode, the fourth embodiment is the same as the first embodiment.

10   With this arrangement, when no assembly tree is displayed on the screen, any erroneous unintended operation for the assembly tree can be prevented.

The processing in step S2122 will be described next in detail.

15   Fig. 22 is a flowchart showing details of the processing in step S2122.

Various operations can be executed for information about the respective parts indicated by the list image, i.e., the so-called assembly tree, as in a

20   general CAD system. Some of the various operations will be described below. Other operations can also be executed for some information indicated by the list image.

It is determined whether a mode to inhibit

25   operations for the assembly tree when the list image is placed outside the display screen of an HMD 110 is set (step S2241).

This mode can be set by the operation unit 3104. Data representing the set mode is stored in the RAM 3102. Hence, in step S2241, it is determined by referring to this data whether the inhibition mode is

5   set.

If YES in step S2241, the processing advances to step S2242 to determine whether the list image is placed in the display screen of the HMD 110 (step S2242). This determination is done by checking, e.g.,

10   whether when the coordinate values of the four corners of the list image in the virtual space are projected in the display screen of the HMD 110, the values are placed in the display screen. For projection, a known projection conversion matrix to display an object in a

15   virtual space onto a display screen is used.

If it is determined that the values are outside the display screen (the list image projects from the display screen of the HMD 110), the processing advances to step S2243 to inhibit operations for the assembly

20   tree (step S2243). That is, any operation for each information indicated by the list image is inhibited. Hence, in this step, the CPU 3101 stops receiving any operation for the assembly tree from the stylus 120.

If NO in step S2241 or NO in step S2242, the

25   processing advances to step S2244 to make the CPU 3101 receive operations for the assembly tree (step S2244).

Data representing the position and orientation of

the stylus 120 in the sensor coordinate system is
stored in the RAM 3102. The data is converted and
projected onto the projection plane to obtain the
position of the stylus 120 on the display screen of the

5   HMD 110 (step S2211). In addition, the positions of
the four corners of each polygon, which forms the list
image, in the display screen of the HMD 110 are
obtained in a similar manner by projection processing.
In which polygon the position of the stylus 120 in the

10   screen is located, i.e., information about which part
is pointed by the stylus 120 is specified (step S2212).

The CPU 3101 checks whether a signal representing
that a stylus button 122 is pressed is input through an
I/F 3107 (step S2213). If YES in step S2213, the

15   processing advances to step S2214 to blink the virtual
object of the part corresponding to the information
described in the polygon (planar virtual object)
pointed by the position of the stylus 120 (step S2214).
More specifically, which planar virtual object has

20   information about which part is managed, as described
above. In addition, information about each part is
associated with data necessary for generating the image
of the part. When the planar virtual object pointed by
the position of the stylus 120 can be specified, the

25   virtual object of the part corresponding to the
information described in the specified planar virtual
object is specified by referring to the association.

Hence, the virtual object of the part can be displayed in the blinking state. The present invention is not limited to blink display. Any other display can be executed when the virtual object of the part pointed by

5   the position of the stylus 120 can visually be recognized.

Fig. 27 is a view showing a display example in which when a planar virtual object 2711 with a description "upper paper cassette" is pointed by the

10 position of the stylus 120 in a list image 2701, a corresponding part 2712 in a virtual object 170 of a copying machine blinks.

The names of parts included in an apparatus "printer X" are listed in the list image. The stylus

15 120 is located in the display region of the planar virtual object 2711. In addition, the stylus button 122 is pressed. Hence, the virtual object of the corresponding part 2712 ("upper paper cassette") blinks.

20 Processing of determining on the basis of the distance between the position of the stylus 120 and the virtual object 170 up to which layer level in the parent/child structure of the parts included in the virtual object 170 is to be presented by the list image

25 will be described next.

Fig. 24 is a view showing a display example of the list image which is displayed when the stylus 120

is moved close to the virtual object 170 of the copying

machine. In this case, of the parent/child structure

of the parts included in the virtual object 170

(printer X), only the names of the parts of the

5   uppermost layer are displayed in a list image 2401.

Referring to Fig. 24, "console module", "right side

panel", "upper paper cassette", "lower paper cassette",

and "paper discharge tray" are displayed.

Fig. 25 is a view showing a display example of

10   the list image when the stylus 120 is further moved

close to a console module 500. Only the names of parts

(parts belong to the layer immediately under the layer

to which the console module 500 belongs) corresponding

to the children of the console module 500 are displayed

15   in a list image 2501. Referring to Fig. 25, "liquid

crystal display panel", "online button", "up button",

"down button", "right button", and "left button" are

displayed. Fig. 25 shows only the names of the parts

included in the console module 500. The names of the

20   parts included in the console module 500 may be

displayed while keeping the layer shown in Fig. 24

displayed.

Fig. 23 is a flowchart of processing of

determining on the basis of the distance between the

25   position of the stylus 120 and the virtual object up to

which layer level in the parent/child structure of the

parts included in the virtual object is to be presented

by the list image. Processing according to the
flowchart shown in Fig. 23 is executed in generating
the list image.

It is determined whether a mode to inhibit

5   operations for the assembly tree when the list image is
placed outside the display screen of the HMD 110 is set
(step S2241).

This mode can be set by the operation unit 3104.
Data representing the set mode is stored in the RAM

10   3102. Hence, in step S2241, it is determined by
referring to this data whether the inhibition mode is
set.

If YES in step S2241, the processing advances to
step S2242 to determine whether the list image is

15   placed in the display screen of the HMD 110 (step
S2242). This determination is done by checking, e.g.,
whether when the coordinate values of the four corners
of the list image in the virtual space are projected in
the display screen of the HMD 110, the values are

20   placed in the display screen. For projection, a known
projection conversion matrix to display an object in a
virtual space onto a display screen is used.

If it is determined that the values are outside
the display screen (the list image projects from the

25   display screen of the HMD 110), the processing advances
to step S2243 to inhibit operations for the assembly
tree (step S2243). That is, any operation for each

information indicated by the list image is inhibited. Hence, in this step, the CPU 3101 stops receiving any operation for the assembly tree from the stylus 120.

If NO in step S2241 or NO in step S2242, the
5 processing advances to step S2244 to make the CPU 3101 receive operations for the assembly tree (step S2244).

Next, the part closest to the position (position of a position/orientation sensor receiver 121 in the sensor coordinate system) of the stylus 120 is
10 specified (step S2301). For example, of parts in the uppermost layer of the parent/child structure of the parts included in the virtual object, i.e., of the most roughly divided parts (in the virtual object 170, the parts displayed in the list image shown in Fig. 24),
15 the part closest to the position of the stylus 120 is specified. Each of the "most roughly divided parts" (parent parts) has at least part (child part) corresponding to the child. As the position of the parent part, the barycenter of the positions of the
20 child parts included in the parent part is used. Processing of obtaining the distance between the barycenter and the position of the stylus 120 is executed for all parent parts, thereby specifying the parent part closest to the position of the stylus 120.

25 The distance between the specified part and the stylus 120 is referred to (step S2302). Up to which layer is to be displayed is determined in accordance

with the referred distance (step S2303).

Fig. 13 is a view showing the assembly tree of parts included in a virtual object A. Such an assembly tree is stored in an external storage device 3106 as data to display the virtual object A. The virtual object A is roughly divided into a part A1, part A2, and part A3. The layer to which the part A1, part A2, and part A3 belong is called layer 1.

The part A2 includes a part A21 and part A22. The part A3 includes a part A31, part A32, and part A33. The layer to which the part A21, part A22, part A31, part A32, and part A33 belong is called layer 2.

The part A22 includes a part A221 and part A222. The layer to which the part A221 and part A222 belong is called layer 3.

As described above, generally, a virtual object is managed by a hierarchical structure based on the parent/child relationship between parts. The location of a part in the hierarchical structure can be expressed by the layer to which the part belongs.

In step S2303, it is determined in accordance with the distance between the stylus 120 and the part specified in step S2301 whether to display information about the parts belonging to layers 0 and 1, information about the parts belonging to layers 0 to 2, or information about the parts belonging to layers 0 to 3. For example, when the distance is 50 cm or more,

pieces of information about the parts belonging to only

layers 0 and 1 are displayed. When the distance is 25

to 50 cm, pieces of information about the parts

belonging to layers 0 to 2 are displayed. When the

5   distance is 25 cm or less, pieces of information about

the parts belonging to layers 0 to 3 are displayed. In

this way, as the distance shortens, pieces of

information about the parts belonging to lower layers

are displayed.

10   Hence, in the assembly tree, determining layers

of parts whose information should be displayed is

equivalent to selecting the node between the layers.

        The layers to be displayed are determined in step

S2303. Next, a list image is generated by using

15   information about the parts belonging to the layers to

be displayed, as described above (step S2304).

        Fig. 26 is a view showing a display example of

the list image of a portion pointed by gesture. When

the stylus 120 is moved to enclose the virtual part

20   corresponding to the node to be selected, the node to

display details is selected. In this example, the

upper paper cassette is selected. As a result, an

assembly tree 2601 is displayed.

        The flow of this processing will be described

25   with reference to the flowchart shown in Fig. 28.

Fig. 28 is a flowchart of processing of displaying the

list image of a portion pointed by gesture. Actually,

this processing is executed in step S404.

It is determined whether a mode to inhibit operations for the assembly tree when the list image is placed outside the display screen of the HMD 110 is set
5   (step S2241).

This mode can be set by the operation unit 3104. Data representing the set mode is stored in the RAM 3102. Hence, in step S2241, it is determined by referring to this data whether the inhibition mode is
10   set.

If YES in step S2241, the processing advances to step S2242 to determine whether the list image is placed in the display screen of the HMD 110 (step S2242). This determination is done by checking, e.g.,
15   whether when the coordinate values of the four corners of the list image in the virtual space are projected in the display screen of the HMD 110, the values are placed in the display screen. For projection, a known projection conversion matrix to display an object in a
20   virtual space onto a display screen is used.

If it is determined that the values are outside the display screen (the list image projects from the display screen of the HMD 110), the processing advances to step S2243 to inhibit operations for the assembly
25   tree (step S2243). That is, any operation for each information indicated by the list image is inhibited. Hence, in this step, the CPU 3101 stops receiving any

operation for the assembly tree from the stylus 120.

If NO in step S2241 or NO in step S2242, the processing advances to step S2244 to make the CPU 3101 receive operations for the assembly tree (step S2244).

5   Next, the presence/absence of gesture input is determined (step S2801). If no gesture input is done, selection of a node to display details is ended. Recognition of presence/absence of gesture input is a known technique. In this embodiment, for example, the

10   motion of the stylus 120 is always monitored, and pattern matching between the trajectory and a circle, triangle, or rectangle is executed. When the patterns match, the presence of gesture is recognized. Alternatively, when the stylus moves reciprocally to

15   the left and right or up and down, the presence/absence of gesture input can be detected by recognizing the motion of a predetermined distance or more in reverse directions a predetermined number of times or more in a predetermined time.

20   If YES in step S2801, it is determined whether the gesture selects a detail display node (step S2802). In this embodiment, a detail display node is selected by drawing a circle (step S2803).

If YES in step S2802, the node closest to the

25   stylus 120 is selected (step S2803). As described above, the layer of the node can also be selected on the basis of the distance between the part and the

position of the stylus 120.

The display contents of the assembly tree are updated to display details of the selected node (step S2804).

5   With the above processing, the node to display details can easily be selected by gesture.

When the position is also designated in the depth direction as indicated by the dotted line in Fig. 29, in addition to the gesture described with reference to

10   Fig. 26, the target node can be designated in more detail.

When semitransparent CAD data is displayed in designating the node by gesture, the node of a part which does not appear on the outer appearance can be

15   designated.

In the semitransparent processing, the semitransparent region can be expanded with time outward from the portion near the stylus. With this processing, the easily recognizable opaque state of the

20   CAD data can be held as much as possible. To designate a wider range by the stylus, it is located at one point for a long time so that the position and orientation can be designated by the stylus.

When a predetermined distance range from the

25   stylus is set semitransparent, position designation by the stylus can be facilitated. When the distance to set transparent is adjusted in accordance with the size

of the target CAD data, a more convenient system can be built.

[Fifth Embodiment]

In this embodiment, list image display is adjusted in addition to the above-described embodiments.

In the mixed reality system, generally, it is difficult to acquire accurate depth information of a moving real object such as a human hand. Hence, composition is basically done by only overwriting a virtual space image on a real image (physical space image).

For this reason, even when a physical object is located in front of a virtual object, the physical object is often occluded by the image of the virtual object. However, the hand of the observer is very significant in practical use. Hence, processing of, e.g., recognizing the flesh color and inhibiting superimposition of the virtual space image on the real image of only the hand portion is executed.

When this processing is added to the processing of the first embodiment, a mixed reality space image as shown in Fig. 15 can be obtained.

Fig. 16 is a flowchart of processing of masking the hand region in the physical space image (real image). Processing according to the flowchart shown in Fig. 16 is executed after the physical space image is

acquired by a RAM 3102 in step S405.

As described above, the image capture thread acquires a physical space image obtained from a video camera 111 of an HMD 110 in step S420. The image is stored in a predetermined area of the RAM 3102 (step S1601). Color data registered in advance in an external storage device 3106 as "hand color" is loaded o the RAM 3102 (loading may be executed in advance). Pixels having the "hand color" are specified in the physical space image acquired in step S1601 by using the data, and the region (to be referred to as a "hand region" hereinafter) formed by the specified pixels is specified (step S1602).

When data representing the "hand color" indicates a "pixel value representing hand color", pixels having the pixel value are specified in step S1602. However, the "hand color" can change depending on the condition of light of outside world and the angle between the hand and light. Hence, data representing the "hand color" may indicate a "range of pixel values representing hand color". In this case, pixels having pixel values in this range are specified in step S1602.

An image (mask image) representing the hand region in the physical space image is generated (step S1603). The physical space image acquired in step S1601 is rendered in a predetermined area of the RAM 3102 (step S1604). The mask image is written in the Z

buffer (depth buffer) of the RAM 3102 (step S1605).

As is known, in processing in step S1605, Z value (when the Z-axis is provided in the direction of line of sight from the position of the viewpoint, the Z

5 value increases in the direction of line of sight) for each pixel of the hand region is written in the Z buffer. The Z value is set, e.g., near the position of the viewpoint. To superimpose the virtual space on the physical space later, the Z buffer is referred to.

10 Since only a portion with Z values larger than the Z value registered in the Z buffer is rendered, the virtual space is not superimposed on the hand region, as shown in Fig. 15.

Various methods can be used to inhibit rendering

15 of the virtual space image on the hand region, and the present invention is not limited to the above-described method. When a known 3D graphics accelerator is mounted in the computer 140, the 3D graphics accelerator masks the specific region by using the Z

20 buffer.

However, display of the assembly tree in the list image is often more important than display of the hand. In this case, the assembly tree must be displayed with priority over the hand. A method of implementing this

25 will be described below.

Fig. 18 is a flowchart of processing of switching between the list image and the hand to preferentially

display one of them. Processing according to the
flowchart shown in Fig. 18, i.e., reception of
operation for switching can be executed before step
S401. Alternatively, the operation may always be

5 received during processing.

A CPU 3101 monitors whether input is done to
instruct display of the list image with priority over
the hand region (display the list image in front of the
hand region) (step S1801). This input can be done by

10 using an operation unit 3104. Alternatively, the
instruction may be input by pressing a stylus button
122 provided on a stylus 120.

When the CPU 3101 detects the input (step S1802),
the processing advances to step S1803. When the flag

15 (status) indicating that the hand region should be
displayed with priority over the list image is
currently ON, the flag is turned off. When the flag is
currently OFF, the flag is turned on (step S1803). The
data of the flag is stored in the RAM 3102. In this

20 step, the current status is obtained by referring to
this data, and the flag is ON/OFF-controlled.

Fig. 17 is a flowchart of processing of switching
between the list image and the hand region to
preferentially display one of them by referring to the

25 flag. Processing according to the flowchart shown in
Fig. 17 is executed in step S406.

As in the first embodiment, an image is rendered

on the physical space image stored in a predetermined area of the RAM 3102 in advance in step S405. At this time, a virtual object image except the list image is rendered (step S1701).

5   It is determined by referring to flag switched in step S1803 whether to display (render) the list image with priority over the hand region (step S1702). If YES in step S1702, the processing advances to step S1704 to render the list image on the image rendered in

10   step S1701 without referring to the Z buffer. As a result, the list image is rendered with priority over the hand region, as shown in Fig. 14.

If NO in step S1702, the processing advances to step S1703 to render the list image on the image

15   rendered in step S1701 while referring to the Z buffer. The Z value "closest to the position of the viewpoint" for each pixel of the hand region is recorded in the Z buffer, as described above. The Z value is referred to, and a pixel having a Z value representing a larger

20   depth than the Z value is not rendered. As a result, the hand region is rendered with priority over the list image.

The priority of display can be switched between the hand region and the list image, as described above.

25   However, the mechanism is not always sufficient because one of them is always preferentially rendered.

Processing will be described below, in which a

mode to display the hand region with priority over the list image as needed, a mode to display the list image at an offset position shifted from the position of the stylus or hand region, and a mode to set the

5   transparency of the list image so high as to see the hand through it while simultaneously displaying the list image and hand region are provided, and operations can be executed while confirming the hand or stylus.

    Fig. 30 is a flowchart of processing related to

10   display of the hand region and list image. Processing according to the flowchart shown in Fig. 30 is executed immediately before list image display in step S405.

    The operator of a computer 140 looks at a list image displayed on the display screen of a display

15   device 3105. If the observer 100 is going to do some operation for displayed information about the respective parts, the operator executes a predetermined operation (e.g., pressing or clicking on a predetermined button) by using the mouse or keyboard

20   included in the operation unit 3104 to change the mode to permit the operation.

    When such operation input is done, the instruction by the operation is sent to the CPU 3101. The CPU 3101 always receives the instruction. When the

25   operation instruction is input, i.e., when the CPU 3101 detects the instruction (step S3001), the processing advances to step S3003 to do setting to execute

processing (processing according to the flowchart shown in Fig. 22) in step S2122, as in the fourth embodiment. Display need not always be the same as in the fourth embodiment. The list image may simply be displayed at an arbitrary position.

If NO in step S3001, the processing advances to step S3002 to determine whether the stylus 120 is being operated (step S3002). For example, when the position and orientation of the stylus 120 do not change by a predetermined amount or more within a predetermined time (e.g., 3 sec) and/or the stylus button 122 is not pressed within a predetermined time, it is determined that the stylus 120 is "not being operated".

If NO in step S3002, the processing advances to step S3003 to execute the above-described processing.

If YES in step S3002, the processing advances to step S3011 to determine by referring to the flag whether to display (render) the list image with priority over the hand region (step S3011).

If YES in step S3011, the processing advances to step S3012 to do setting to render the list image on the already rendered image while referring to the Z buffer (step S3012).

If NO in step S3011, the processing advances to step S3013 to do setting to render the list image on the already rendered image without referring to the Z buffer (step S3013).

It is determined whether the mode to lay out the list image at a position (offset position) shifted from the position of the stylus 120 on the image is set (step S3021). The setting of this mode can be changed, like other modes. Data representing the set mode is stored in the RAM 3102.

If YES in step S3021, the processing advances to step S3022 to do setting to lay out the list image in the virtual space at a position shifted from the position of the stylus 120 by a predetermined distance (step S3022).

If NO in step S3021, the processing advances to step S3023 to do setting to lay out the list image as in the first embodiment (step S3023).

It is determined whether the mode to display a semitransparent list image is set (step S3031). This mode can be set by the operation unit 3104. Data representing the set mode is stored in the RAM 3102. Hence, in step S3031, it is determined by referring to the data whether the semitransparent display mode is set.

If NO in step S3031, the processing advances to step S3033 to generate a polygon having a non-transparent color by controlling the α value of the polygon. Processing of mapping a texture which describes information about the part to the polygon is executed for each part (step S3033). That is, the list

image is generated, as in the first embodiment. This processing also applies to a 2D list image. The list image is generated, as in the first embodiment.

If YES in step S3031, the processing advances to step S3032 to generate a polygon having a transparent color by controlling the α value of the polygon. Processing of mapping a texture which describes information about the part to the polygon is executed for each part, thereby generating the list image (step S3032). This texture is created in advance as transparent except the character portion (the α values of pixels included in portions except the character portion are set transparent).

With the above arrangement, operations can be executed while displaying the assembly tree during the stylus operation and confirming the hand.

The above embodiments can appropriately be combined. In this case, the processing operations in the embodiments are executed in order described above in the embodiments. When the embodiments are combined, they can be modified as needed such that processing to be executed earlier is executed earlier, as is apparent to those skilled in the art.

[Other Embodiment]

The object of the present invention can also be achieved by supplying a recording medium (or storage medium) which records software program codes for

implementing the functions of the above-described embodiments to a system or apparatus and causing the computer (or CPU or MPU) of the system or apparatus to read out and execute the program codes stored in the

5   recording medium. In this case, the program codes read out from the recording medium implement the functions of the above-described embodiments by themselves, and the recording medium which stores the program codes constitutes the present invention.

10   The functions of the above-described embodiments are implemented not only when the readout program codes are executed by the computer but also when the operating system (OS) running on the computer performs part or all of actual processing on the basis of the

15   instructions of the program codes.

The functions of the above-described embodiments are also implemented when the program codes read out from the storage medium are written in the memory of a function expansion board inserted into the computer or

20   a function expansion unit connected to the computer, and the CPU of the function expansion board or function expansion unit performs part or all of actual processing on the basis of the instructions of the program codes.

25   When the present invention is applied to the recording medium, the recording medium stores program codes corresponding to the above-described flowchart

(functional arrangement).

As many apparently widely different embodiments of the present invention can be made without departing from the spirit and scope thereof, it is to be

5   understood that the invention is not limited to the specific embodiments thereof except as defined in the claims.

CLAIM OF PRIORITY

10   This application claims priority from Japanese Patent Application No. 2004-158025 filed on May 27, 2004 and Japanese Patent Application No. 2004-158026 filed on May 27, 2004, the entire contents of which are hereby incorporated by reference herein.

15

CLAIMS

1.   An image processing method of generating an image
of a virtual space formed from a virtual object
including at least one part, characterized by
5   comprising:

        a first acquisition step of acquiring a position
and orientation of a viewpoint of an observer;

        a second acquisition step of acquiring a position
and orientation of a pointing device which is worn by
10   the observer on a hand to execute various kinds of
operations;

        a layout step of laying out a list image to
display a list of pieces of information about the parts
near the position acquired in the second acquisition
15   step;

        a virtual space image generation step of
generating the image of the virtual space after laying
out the list image, which is seen in accordance with
the position and orientation of the viewpoint; and

20   an output step of outputting the image generated
in the virtual space image generation step to a
predetermined display device.

2.   The method according to claim 1, characterized in
25   that in the layout step, the list image is laid out
while making a plane of the list image, on which the
pieces of information about the parts are described,

visible from the position and orientation of the viewpoint.

3. The method according to claim 1, characterized in
5 that in the layout step, the list image is laid out at a position that internally divides a line segment connecting the position acquired in the first acquisition step and the position acquired in the second acquisition step to t : (1-t).
10

4. The method according to claim 1, characterized by further comprising a layout control step of controlling processing in the layout step in accordance with an instruction whether to display the list image to switch
15 whether to contain the list image in the virtual space image.

5. The method according to claim 1, characterized by further comprising a conversion step of converting the
20 list image into a semitransparent image in accordance with an instruction to change the list image to the semitransparent image.

6. The method according to claim 1, characterized by
25 further comprising

a determination step of determining on the basis of the position and orientation of the viewpoint and a

position of the virtual object whether the virtual

object is present in a direction of line of sight of

the viewpoint, and

a transparency control step of, when it is

5   determined in the determination step that the virtual

object is present, making a transparency of the list

image higher than that when it is determined in the

determination step that the virtual object is not

present.

10

7.   The method according to claim 1, characterized by

further comprising

a distance calculation step of calculating a

distance between the position of the pointing device

15   and the position of the virtual object, and

a list image generation step of generating the

list image to display the list of pieces of information

about the parts up to a layer level corresponding to

the distance calculated in the distance calculation

20   step in a hierarchical structure of the parts included

in the virtual object.

8.   The method according to claim 1, characterized in

that the list image is an image to display a list of

25   pieces of information about, of the parts included in

the virtual object, a part at a position closest to the

position of the pointing device acquired in the second

acquisition step.

9.   The method according to claim 1, characterized in that in the virtual space image generation step, when the list image overlaps a hand region in the physical space image acquired in the physical space image acquisition step, the image of the virtual space is generated on the basis of priority data to designate which of the hand region and the list image should be rendered in front.

10.   The method according to claim 9, characterized by further comprising a designation step of designating which of the hand region and the list image should be rendered in front,

          wherein in the designation step, designated contents are set to the priority data.

11.   An image processing method of generating a virtual image corresponding to a position and orientation of an observer and compositing the virtual image with a physical image corresponding to the position and orientation of the observer, including

          acquiring the position and orientation of the observer,

          generating the virtual image in accordance with the position and orientation of the observer, and

compositing the physical image corresponding to
the position and orientation of the observer with the
virtual image, characterized by comprising:
acquiring a position of pointing means operated
5   by the observer;
identifying a part pointed by the pointing means;
generating a part information virtual image to
display information about the identified part; and
determining a layout position of the part
10   information virtual image in accordance with the
position of the pointing means.

12.   The method according to claim 11, characterized
in that the layout position is determined in accordance
15   with the position of the pointing means and the
position and orientation of the observer.

13.   The method according to claim 11, characterized
in that the information about the part comprises a list
20   of a plurality of parts associated with the identified
part.

14.   An image processing apparatus of generating an
image of a virtual space formed from a virtual object
25   including at least one part, characterized by
comprising:
first acquisition unit adapted to acquire a

position and orientation of a viewpoint of an observer;

second acquisition unit adapted to acquire a position and orientation of a pointing device which is worn by the observer on a hand to execute various kinds
5   of operations;

layout unit adapted to lay out a list image to display a list of pieces of information about the parts near the position acquired by said second acquisition unit;

10   virtual space image generation unit adapted to generate the image of the virtual space after laying out the list image, which is seen in accordance with the position and orientation of the viewpoint; and

output unit adapted to output the image generated
15   by said virtual space image generation unit to a predetermined display device.

15.   An image processing apparatus of generating a virtual image corresponding to a position and
20   orientation of an observer and compositing the virtual image with a physical image corresponding to the position and orientation of the observer, comprising:

acquiring unit adapted to acquire the position and orientation of the observer,
25   generating unit adapted to generate the virtual image in accordance with the position and orientation of the observer, and

compositing unit adapted to composite the physical image corresponding to the position and orientation of the observer with the virtual image, characterized by comprising:

5   acquiring unit adapted to acquire a position of pointing means operated by the observer;

identifying unit adapted to identify a part pointed by the pointing means;

generating unit adapted to generate a part

10   information virtual image to display information about the identified part; and

determining unit adapted to determining a layout position of the part information virtual image in accordance with the position of the pointing means.

15

16. A program characterized by causing a computer to execute an image processing method of claim 1.

17. A program characterized by causing a computer to

20   execute an image processing method of claim 11.

ABSTRACT

The position and orientation of the viewpoint of
an observer (100) are acquired. The position and
orientation of a stylus (120) are acquired. A list
5   image is laid out near the position of the stylus
(120). An image of a virtual space after laying out
the list image, which is seen in accordance with the
position and orientation of the viewpoint, generated.
The generated image is output to the display screen of
10   an HMD (110).

F I G. 1

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INVENTOR: KENJI MORITA ET AL.
TITLE: INFORMATION PROCESSING
METHOD, INFORMATION PROCESSING
APPARATUS, IMAGE SENSING ETC.
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212-218-2100

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F I G. 2

INVENTOR: KENJI MORITA ET AL.
TITLE: INFORMATION PROCESSING
METHOD, INFORMATION PROCESSING
APPARATUS, IMAGE SENSING ETC.
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F I G. 3

FIG. 4

START

S401
START POSITION/
ORIENTATION THREAD

S402
START IMAGE CAPTURE THREAD

S410
OUTPUT FROM POSITION/
ORIENTATION THREAD

S403
UPDATE POSITIONS AND
ORIENTATIONS OF HMD AND STYLUS

S404
UPDATE VIRTUAL SPACE STATE

S420
OUTPUT FROM IMAGE
CAPTURE THREAD

S405
RENDER PHYSICAL SPACE IMAGE

S406
RENDER VIRTUAL SPACE IMAGE

S407
OUTPUT COMPOSITED IMAGE

S408
END NOTIFICATION?
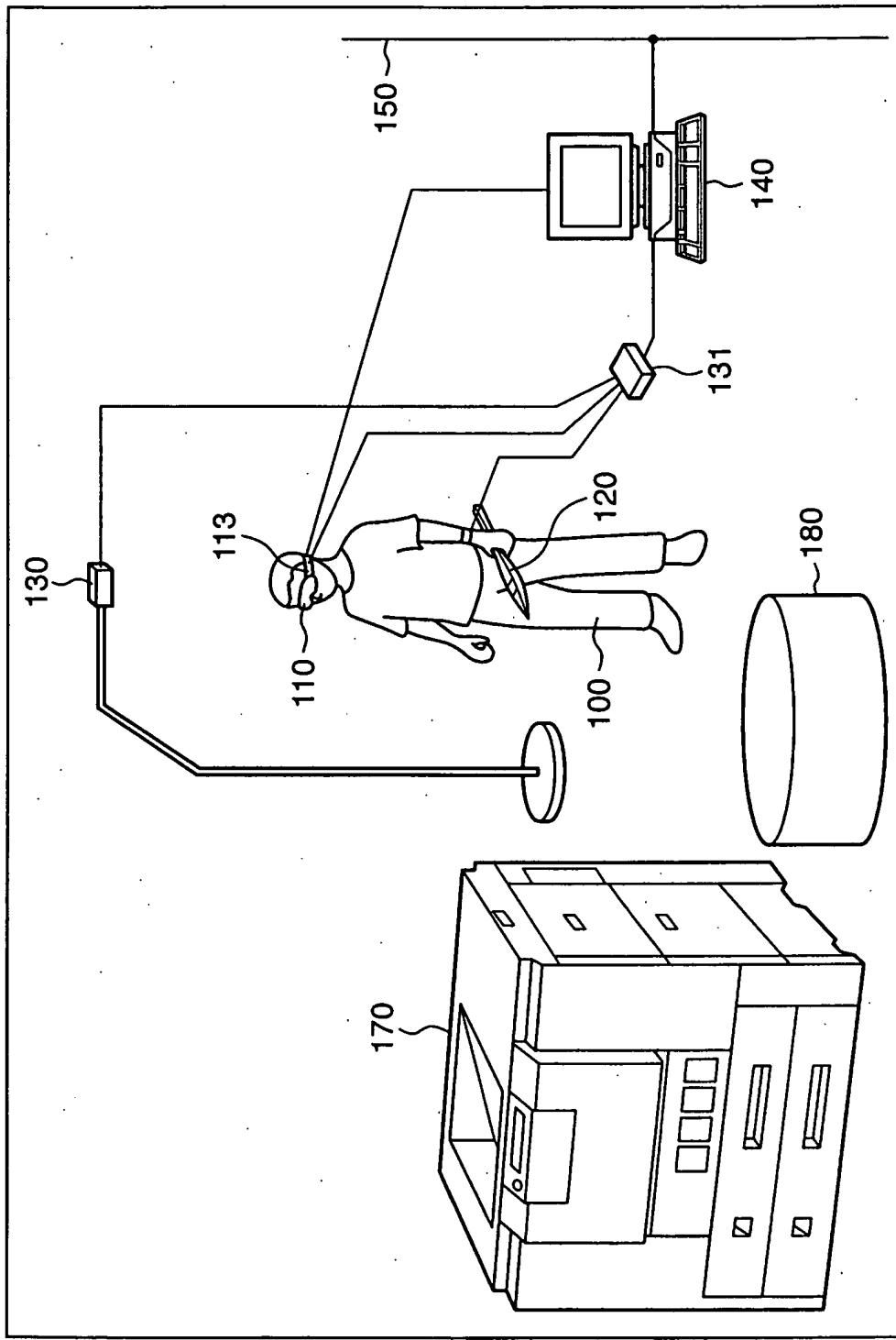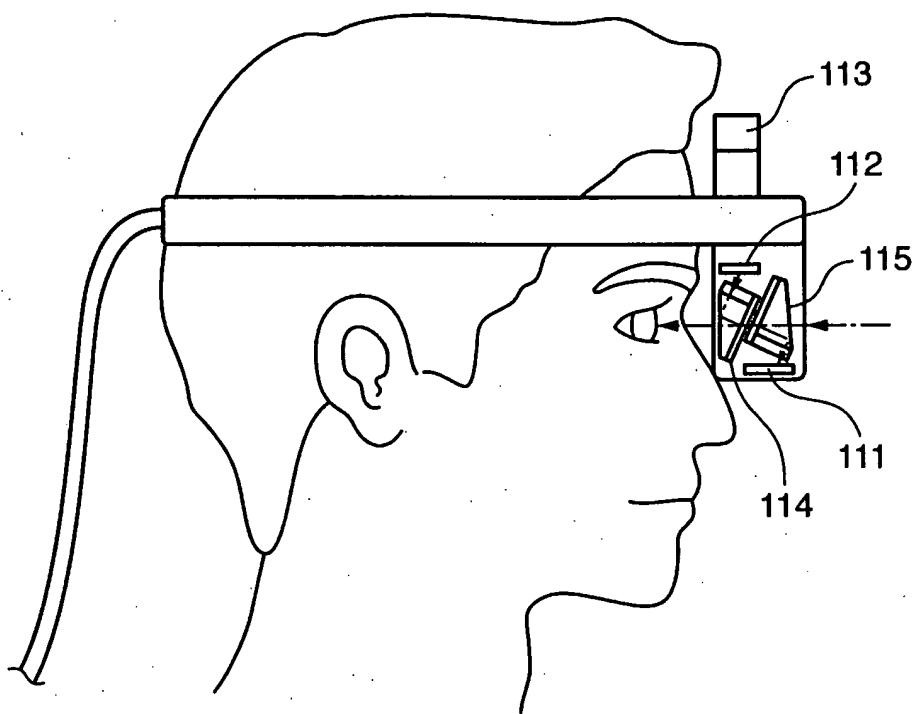
NO

YES

END OF MAIN THREAD

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INVENTOR: KENJI MORITA ET AL.
TITLE: INFORMATION PROCESSING
METHOD, INFORMATION PROCESSING
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F I G. 5

F I G. 6

601

```
CONSOLE MODULE
    ├─ LIQUID CRYSTAL DISPLAY PANEL
    │      ├─ LIQUID CRYSTAL MATERIAL
    │      └─ LIQUID CRYSTAL DISPLAY TEXTURE
    ├─ ONLINE BUTTON
    │      ├─ ONLINE BUTTON MATERIAL
    │      └─ ONLINE BUTTON TEXTURE
    ├─ DISCHARGE BUTTON
    │      ├─ DISCHARGE BUTTON MATERIAL
    │      └─ DISCHARGE BUTTON TEXTURE
    ├─ UP BUTTON
    │      ├─ UP BUTTON MATERIAL
    │      └─ UP BUTTON TEXTURE
    ├─ DOWN BUTTON
    │      ├─ DOWN BUTTON MATERIAL
    │      └─ DOWN BUTTON TEXTURE
    ├─ RIGHT BUTTON
    │      ├─ RIGHT BUTTON MATERIAL
    │      └─ RIGHT BUTTON TEXTURE
    └─ LEFT BUTTON
           ├─ LEFT BUTTON MATERIAL
           └─ LEFT BUTTON TEXTURE
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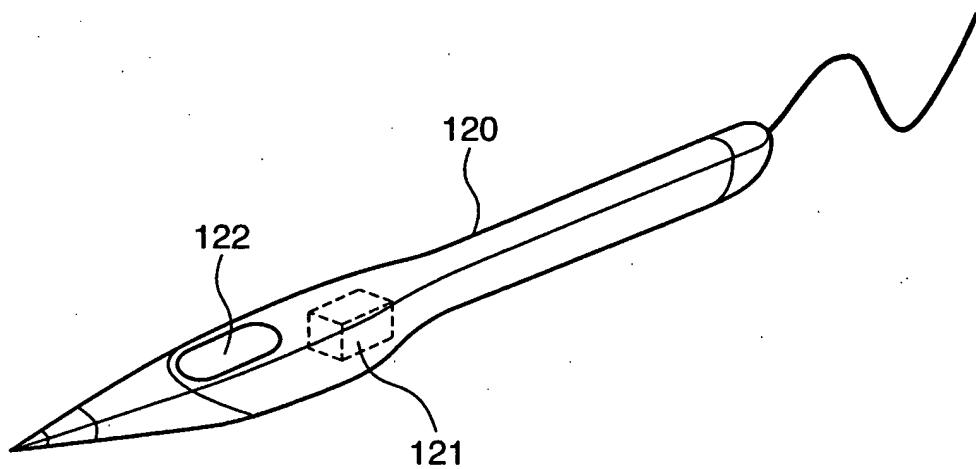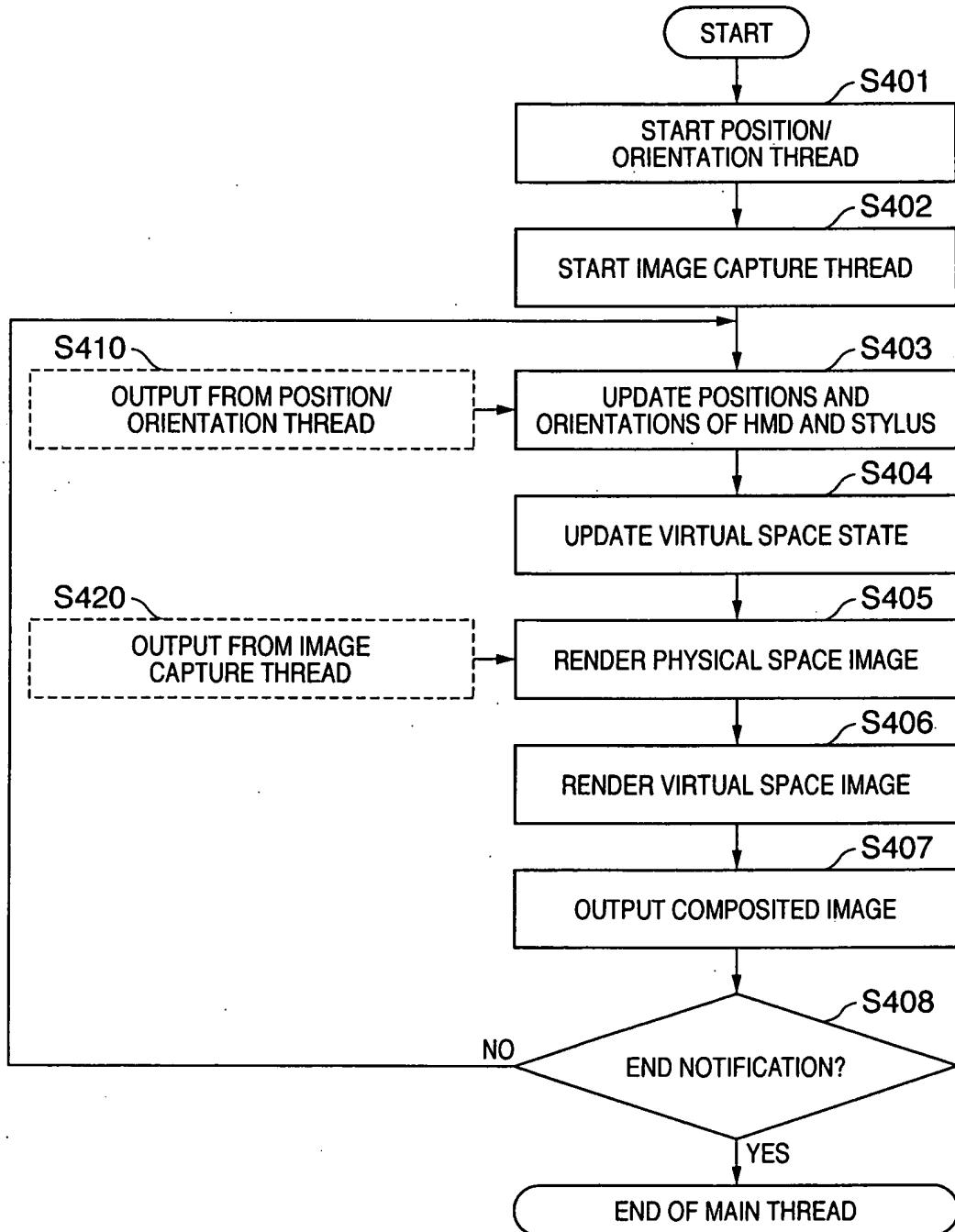
INVENTOR: KENJI MORITA ET AL.
TITLE: INFORMATION PROCESSING
METHOD, INFORMATION PROCESSING
APPARATUS, IMAGE SENSING ETC.
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FIG. 7

701

CONSOLE MODULE
├── LIQUID CRYSTAL DISPLAY PANEL
│   ├── LIQUID CRYSTAL MATERIAL
│   └── LIQUID CRYSTAL DISPLAY TEXTURE
├── ONLINE BUTTON
│   ├── ONLINE BUTTON MATERIAL
│   └── ONLINE BUTTON TEXTURE
├── DISCHARGE BUTTON
│   ├── DISCHARGE BUTTON MATERIAL
│   └── DISCHARGE BUTTON TEXTURE
├── UP BUTTON
│   ├── UP BUTTON MATERIAL
│   └── UP BUTTON TEXTURE
├── DOWN BUTTON
│   ├── DOWN BUTTON MATERIAL
│   └── DOWN BUTTON TEXTURE
├── RIGHT BUTTON
│   ├── RIGHT BUTTON MATERIAL
│   └── RIGHT BUTTON TEXTURE
├── LEFT BUTTON
│   ├── LEFT BUTTON MATERIAL
│   └── LEFT BUTTON TEXTURE

170

120

FIG. 8

801

CONSOLE MODULE
├─ LIQUID CRYSTAL DISPLAY PANEL
│ ├─ LIQUID CRYSTAL MATERIAL
│ └─ LIQUID CRYSTAL DISPLAY TEXTURE
├─ ONLINE BUTTON
│ ├─ ONLINE BUTTON MATERIAL
│ └─ ONLINE BUTTON TEXTURE
├─ DISCHARGE BUTTON
│ ├─ DISCHARGE BUTTON MATERIAL
│ └─ DISCHARGE BUTTON TEXTURE
├─ UP BUTTON
│ ├─ UP BUTTON MATERIAL
│ └─ UP BUTTON TEXTURE
├─ DOWN BUTTON
│ ├─ DOWN BUTTON MATERIAL
│ └─ DOWN BUTTON TEXTURE
├─ RIGHT BUTTON
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├─ LEFT BUTTON
│ ├─ LEFT BUTTON MATERIAL
│ └─ LEFT BUTTON TEXTURE

170

120
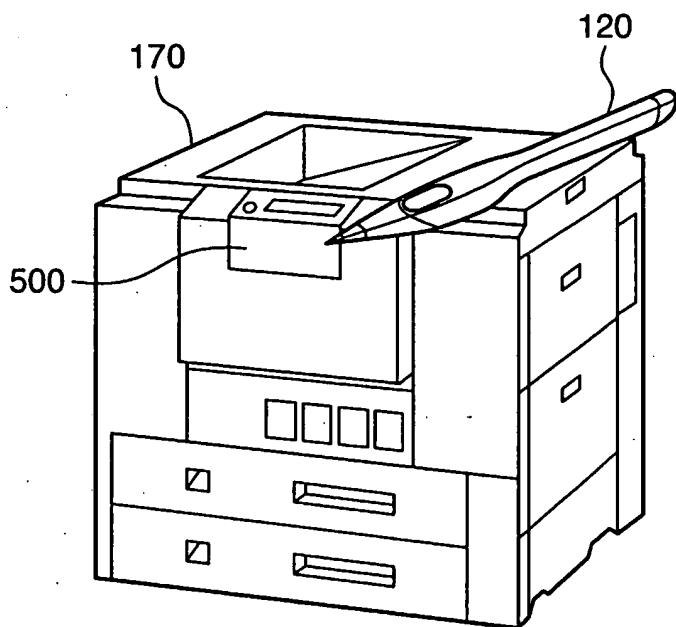
INVENTOR: KENJI MORITA ET AL.
TITLE: INFORMATION PROCESSING
METHOD, INFORMATION PROCESSING
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F I G. 9

901

CONSOLE MODULE
├─ LIQUID CRYSTAL DISPLAY PANEL
│ ├ LIQUID CRYSTAL MATERIAL
│ └ LIQUID CRYSTAL DISPLAY TEXTURE
├─ ONLINE BUTTON
│ ├ ONLINE BUTTON MATERIAL
│ └ ONLINE BUTTON TEXTURE
├─ DISCHARGE BUTTON
│ ├ DISCHARGE BUTTON MATERIAL
│ └ DISCHARGE BUTTON TEXTURE
├─ UP BUTTON
│ ├ UP BUTTON MATERIAL
│ └ UP BUTTON TEXTURE
├─ DOWN BUTTON
│ ├ DOWN BUTTON MATERIAL
│ └ DOWN BUTTON TEXTURE
├─ RIGHT BUTTON
│ ├ RIGHT BUTTON MATERIAL
│ └ RIGHT BUTTON TEXTURE
└─ LEFT BUTTON
   ├ LEFT BUTTON MATERIAL
   └ LEFT BUTTON TEXTURE

170

120

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INVENTOR: KENJI MORITA ET AL.
TITLE: INFORMATION PROCESSING
METHOD, INFORMATION PROCESSING
APPARATUS, IMAGE SENSING ETC.
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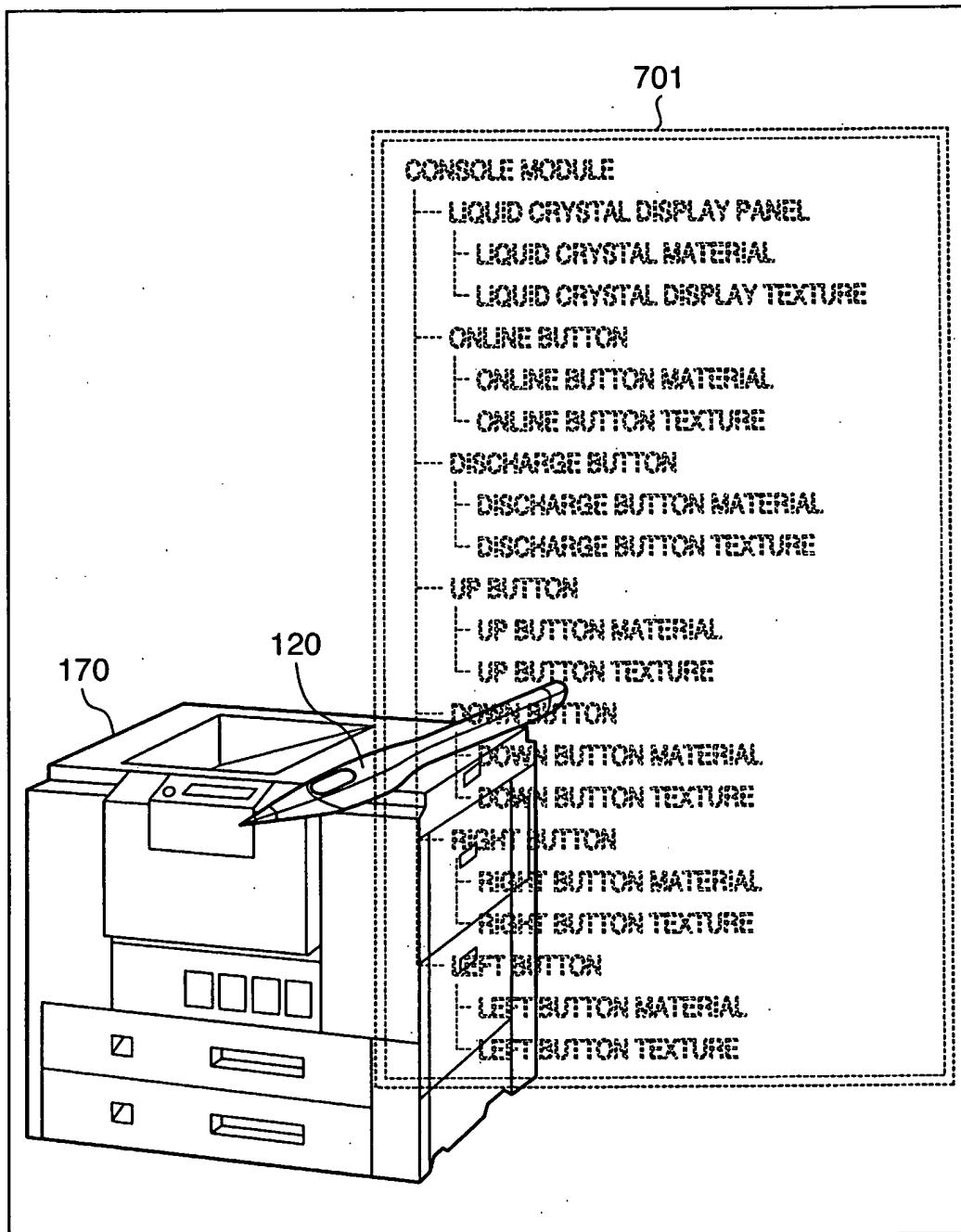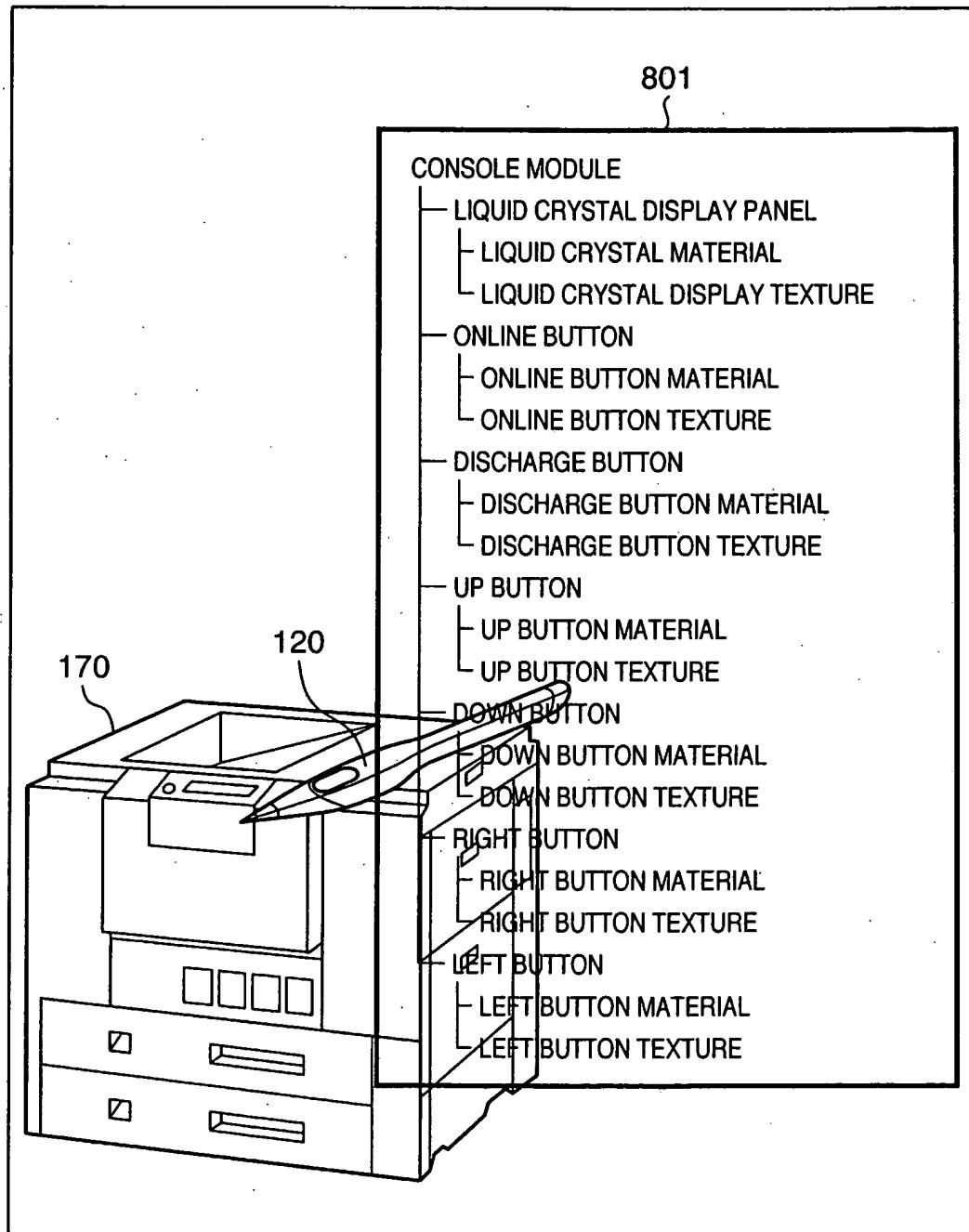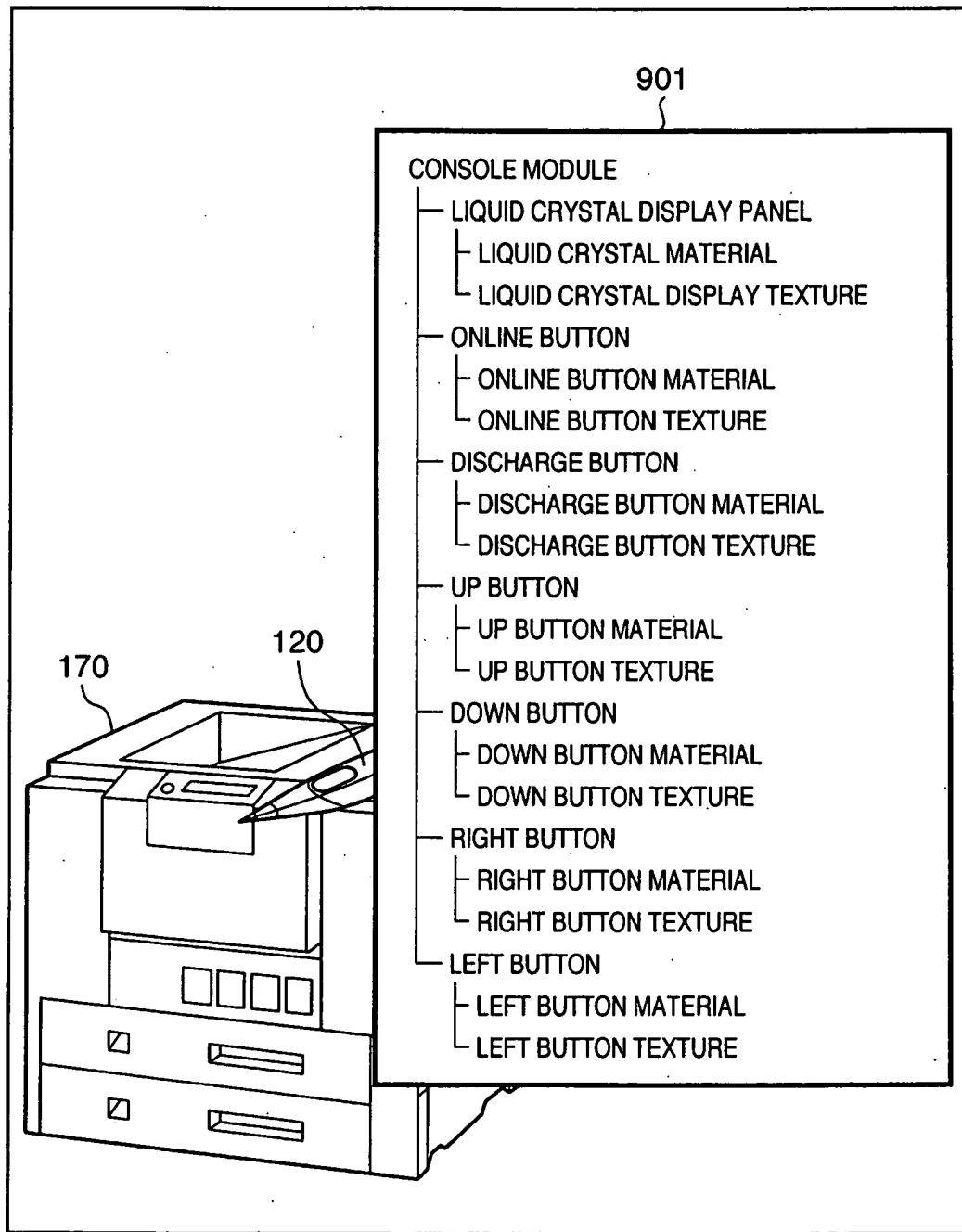NEW YORK, NEW YORK 10112
212-218-2100
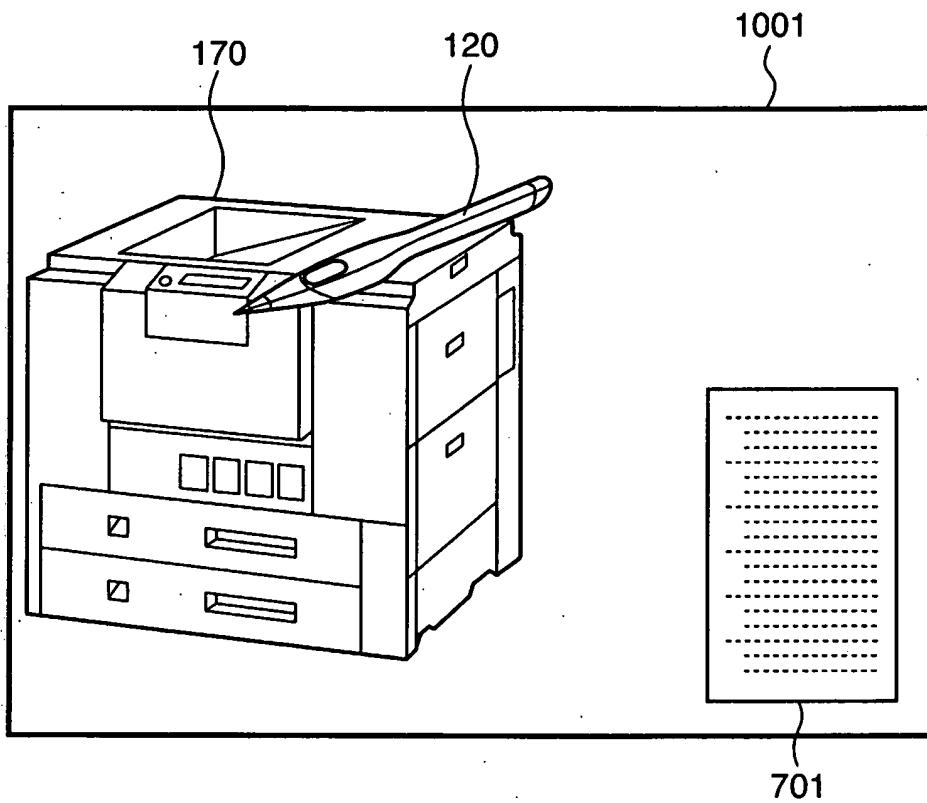
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F I G. 10

F I G. 11

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INVENTOR: KENJI MORITA ET AL.
TITLE: INFORMATION PROCESSING
METHOD, INFORMATION PROCESSING
APPARATUS, IMAGE SENSING ETC.
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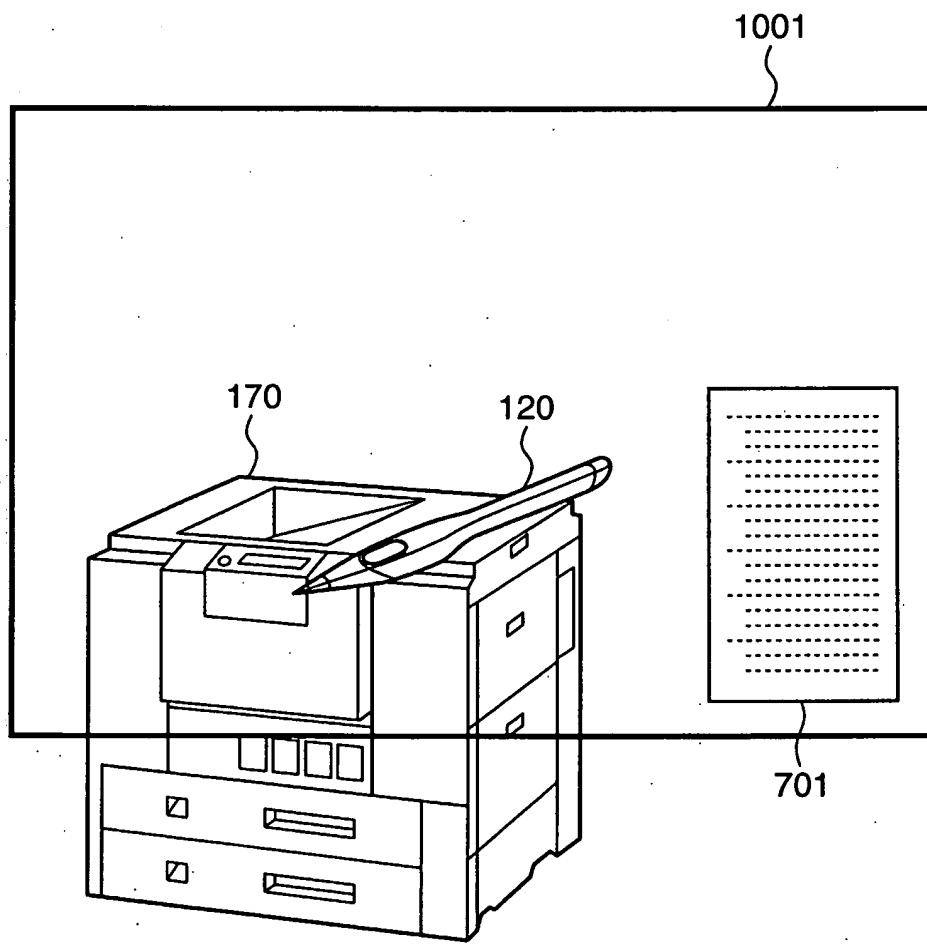212-218-2100

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F I G. 12

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INVENTOR: KENJI MORITA ET AL.
TITLE: INFORMATION PROCESSING
METHOD, INFORMATION PROCESSING
APPARATUS, IMAGE SENSING ETC.
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F I G. 13

LAYER 0   LAYER 1   LAYER 2   LAYER 3

A ————— A_1 —————

A_2 ————— A_{21}

A_{22} ————— A_{221}

A_{222}

A_3 ————— A_{31}

A_{32}

A_{33}

INVENTOR: KENJI MORITA ET AL.
TITLE: INFORMATION PROCESSING
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F I G. 14
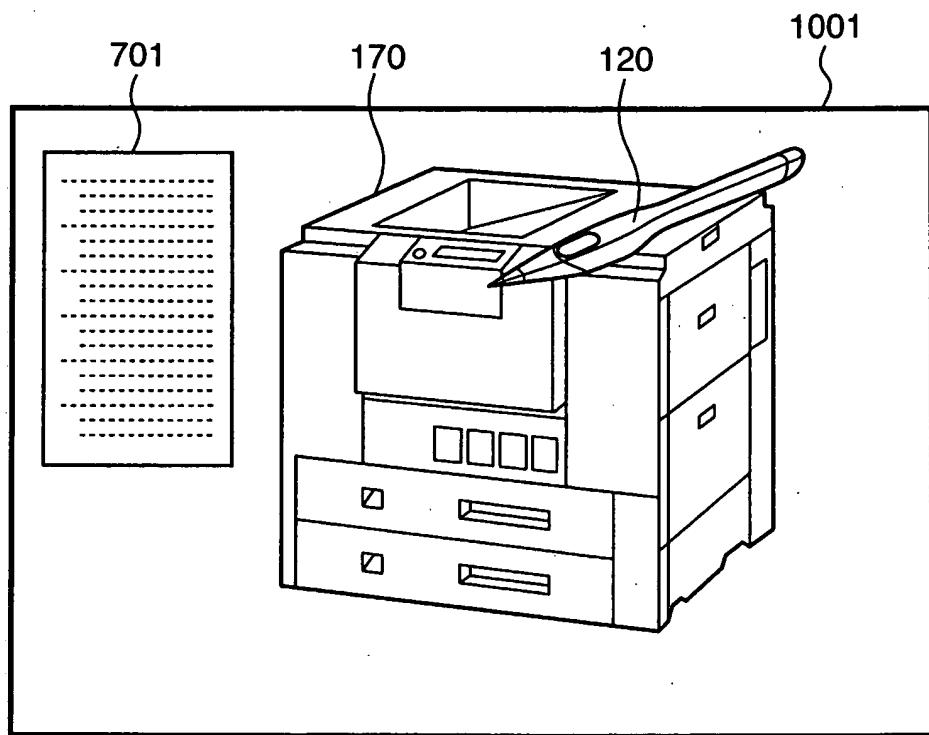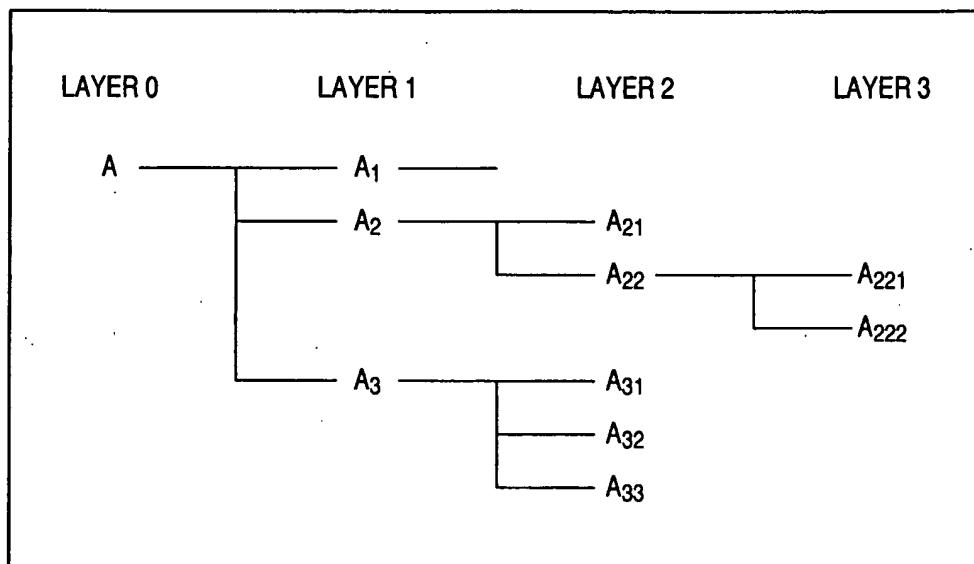
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F I G. 15

901

CONSOLE MODULE
— LIQUID CRYSTAL DISPLAY PANEL
    ├ LIQUID CRYSTAL MATERIAL
    └ LIQUID CRYSTAL DISPLAY TEXTURE
— ONLINE BUTTON
    ├ ONLINE BUTTON MATERIAL
    └ ONLINE BUTTON TEXTURE
— DISCHARGE BUTTON
    ├ DISCHARGE BUTTON MATERIAL
    └ DISCHARGE BUTTON TEXTURE
— UP BUTTON
    ├ UP BUTTON MATERIAL
    └ UP BUTTON TEXTURE
DOWN BUTTON
DOWN BUTTON MATERIAL
DOWN BUTTON TEXTURE
GHT BUTTON
RIGHT BUTTON MATERIAL
RIGHT BUTTON TEXTURE
T BUTTON
FT BUTTON MATERIAL
FT BUTTON TEXTURE

1401

170

F I G. 16

START

ACQUIRE REAL IMAGE — S1601

EXTRACT FLESH COLOR REGION — S1602

GENERATE FLESH COLOR REGION MASK IMAGE — S1603

RENDER REAL IMAGE — S1604

WRITE FLESH COLOR REGION
MASK IMAGE IN DEPTH BUFFER — S1605

END OF REAL IMAGE RENDERING

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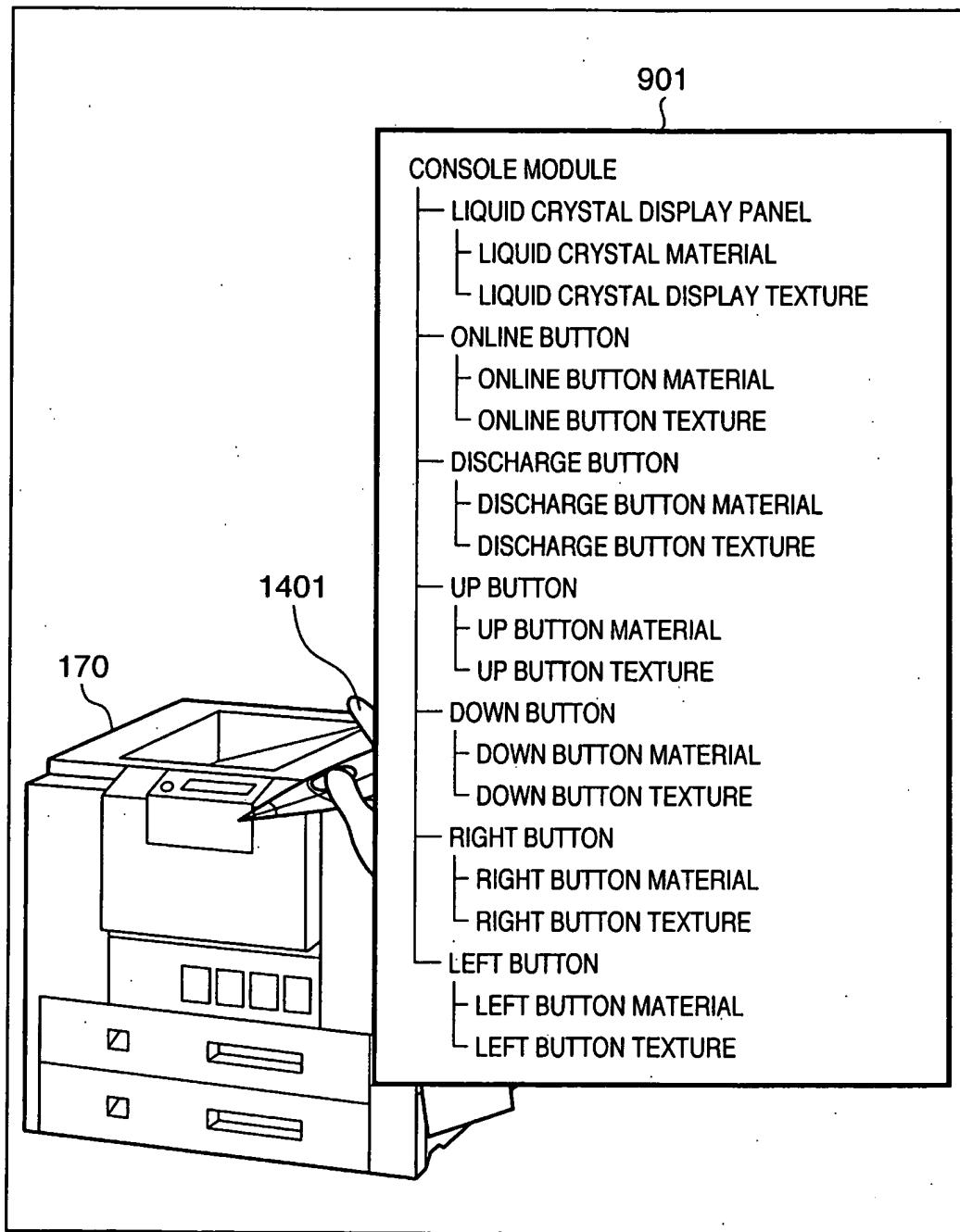30 ROCKEFELLER PLAZA
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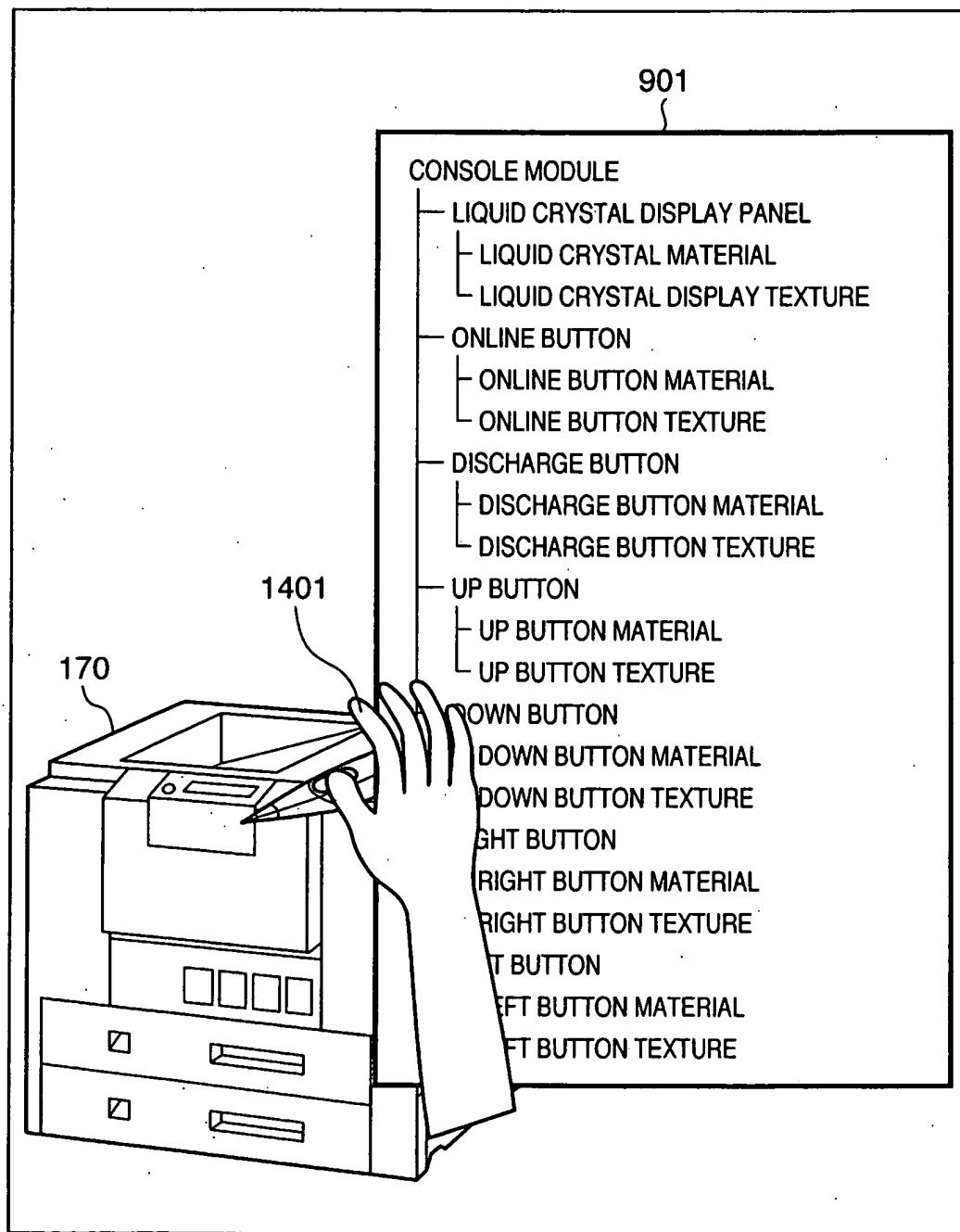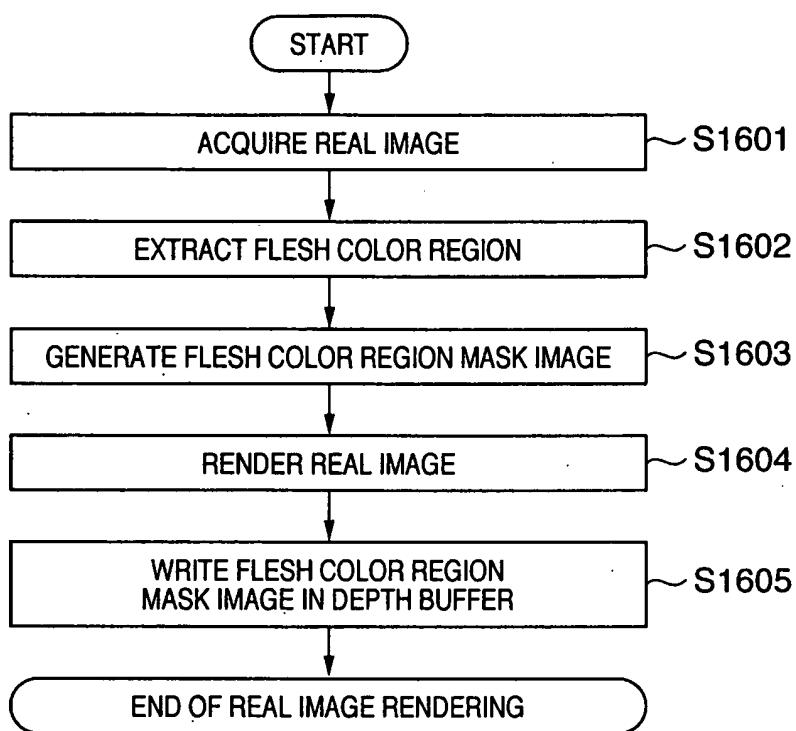212-218-2100

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F I G. 17

F I G. 18

START

INPUT BUTTON ~S1801

S1802

NO ← INPUT?

YES

INVERT HAND MASK
OVERWRITE ON/OFF STATUS ~S1803

END OF UPDATING OF HAND MASK
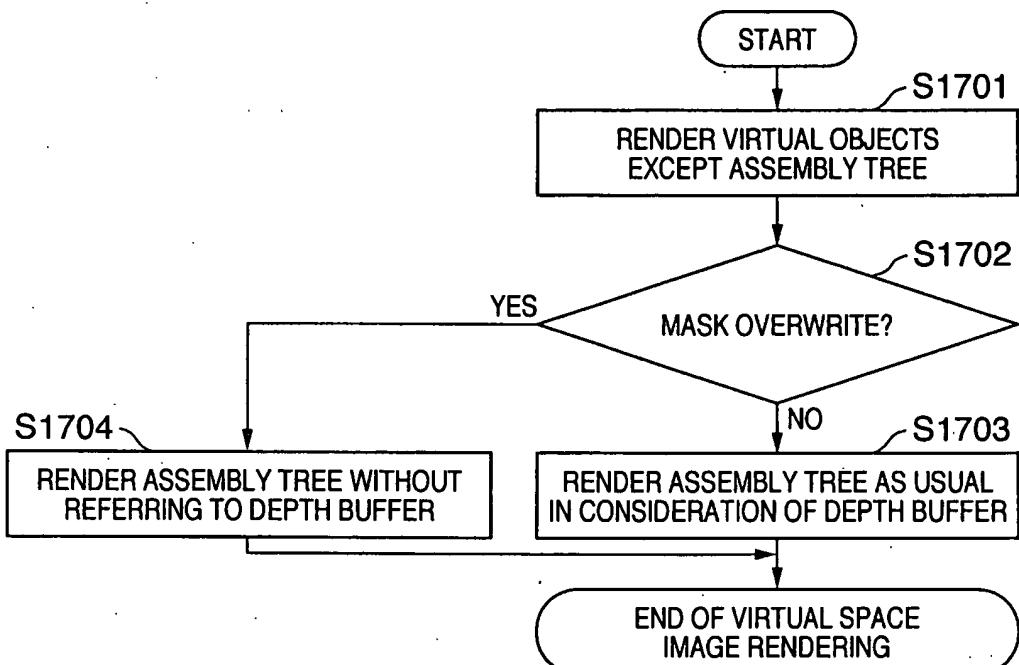OVERWRITE ON/OFF SETTING

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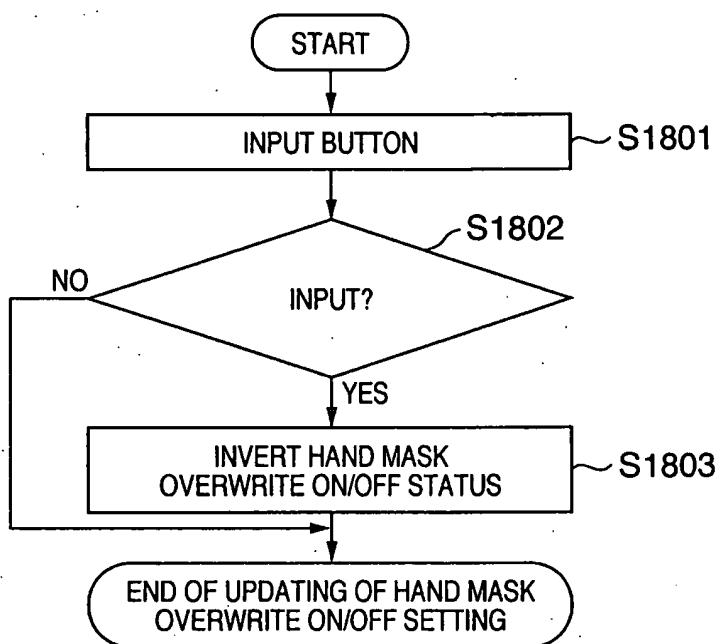30 ROCKEFELLER PLAZA
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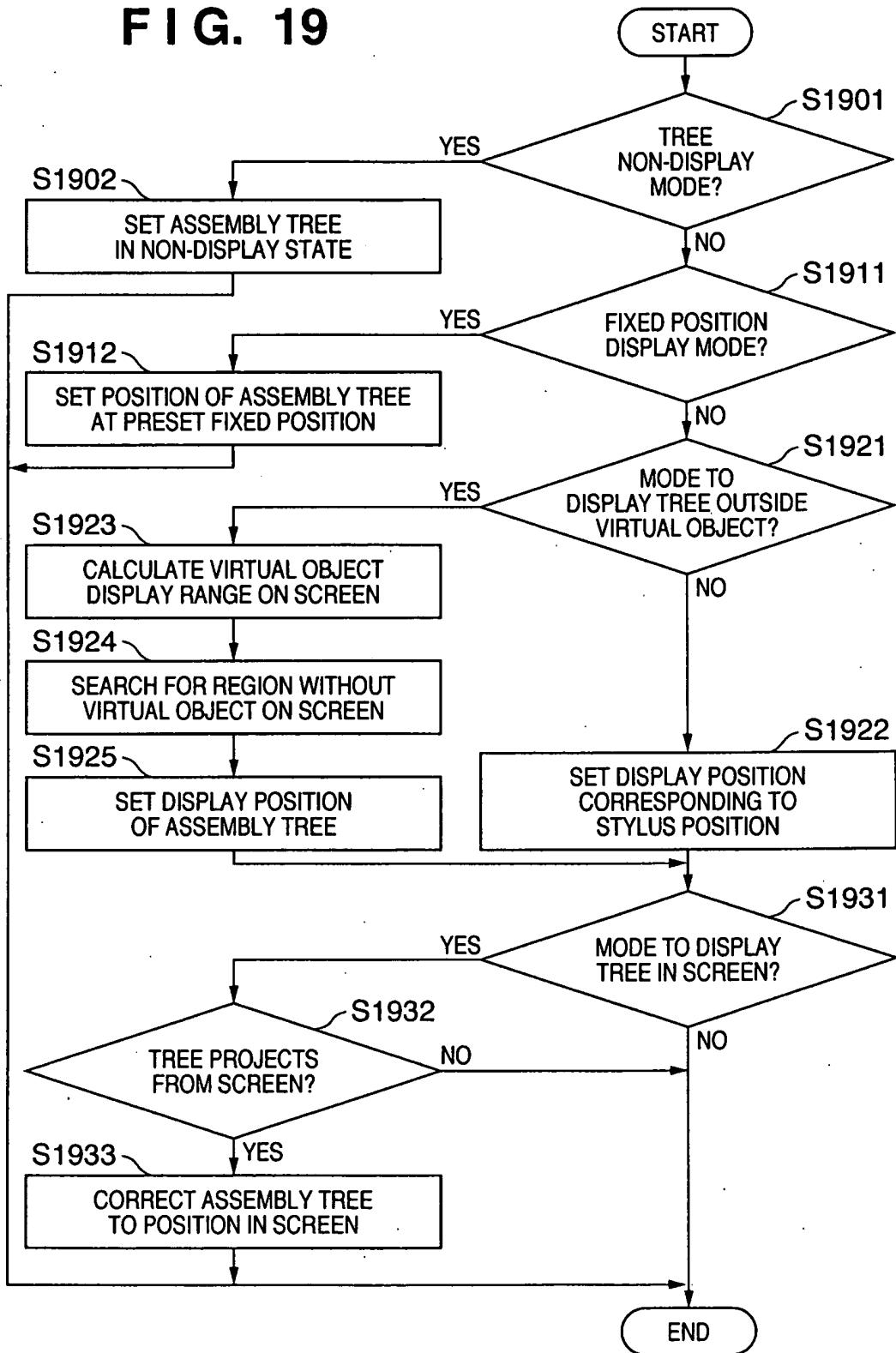212-218-2100

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FIG. 19

F I G. 20

START

S2010

MODE TO DISPLAY
SEMITRANSPARENT TREE
WHEN VIRTUAL OBJECT
OVERLAPS LINE OF
SIGHT?

NO

YES S2012

CALCULATE ANGLE BETWEEN
DIRECTION OF VIRTUAL OBJECT AND
DIRECTION OF LINE OF SIGHT

S2020

DIRECTION OF
VIRTUAL OBJECT
MATCHES DIRECTION OF
LINE OF SIGHT?

NO

YES S2021

S2022

SET ASSEMBLY TREE TO
NORMAL TRANSPARENCY

SET ASSEMBLY TREE TO
TRANSPARENCY IN CASE OF
DISPLAY OVERLAP

END

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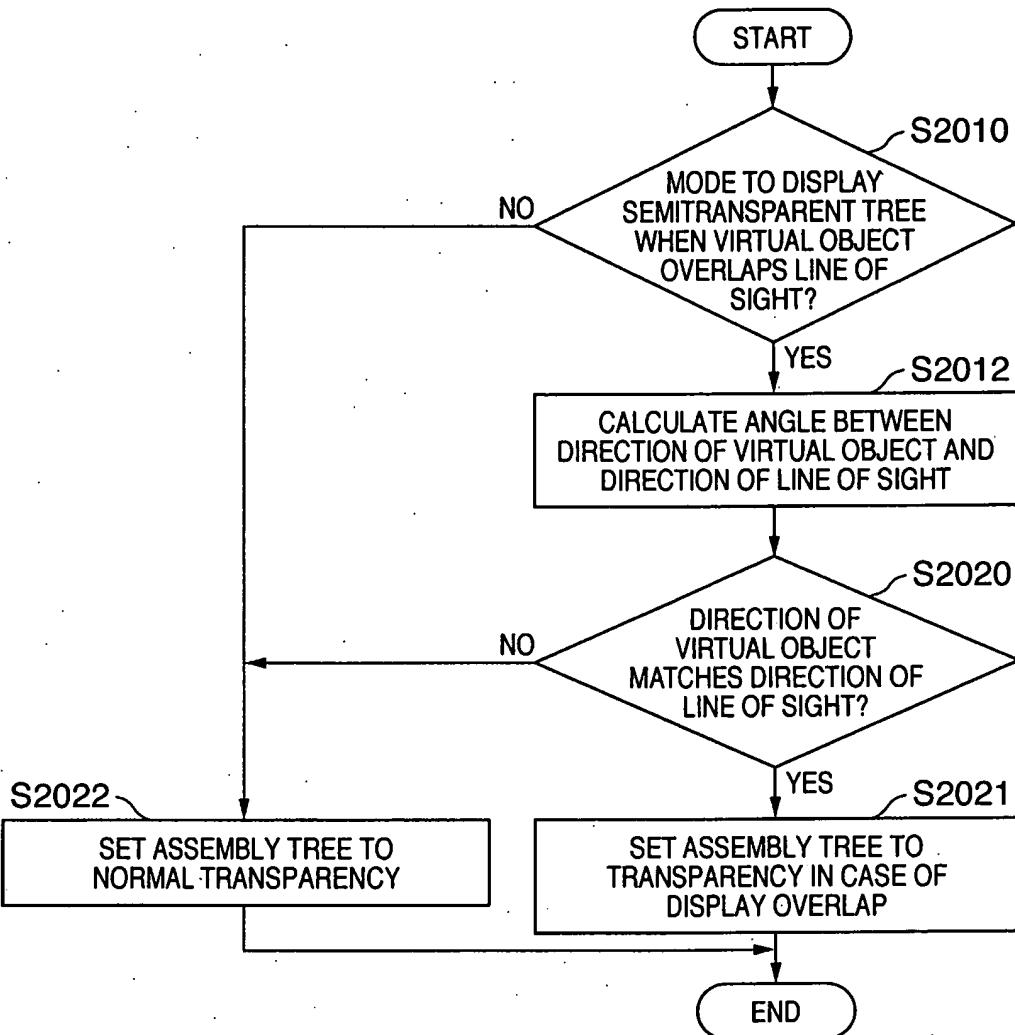NEW YORK, NEW YORK 10112
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F I G. 21

FIG. 22

FIG. 23

START

S2241

MODE TO INHIBIT OPERATION FOR TREE OUTSIDE FIELD OF VIEW?

YES

S2242

TREE OUTSIDE FIELD OF VIEW?

NO

NO

S2243

INHIBIT ASSEMBLY TREE OPERATION

YES

END

S2244

PERMIT ASSEMBLY TREE OPERATION

S2301

SELECT PART ON VIRTUAL OBJECT CLOSEST TO STYLUS POINT

S2302

CALCULATE DISTANCE BETWEEN STYLUS POINT AND CLOSEST PART

S2303

SELECT NODE OF ASSEMBLY TREE TO BE DISPLAYED DETAILS IN ACCORDANCE WITH DISTANCE

S2304

UPDATE DISPLAY CONTENTS OF ASSEMBLY TREE IN ACCORDANCE WITH TOP OF SELECTED ASSEMBLY TREE

END

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F I G. 24

2401

PRINTER X
— CONSOLE MODULE
— RIGHT SIDE PANEL
— UPPER PAPER CASSETTE
— LOWER PAPER CASSETTE
— PAPER DISCHARGE TRAY
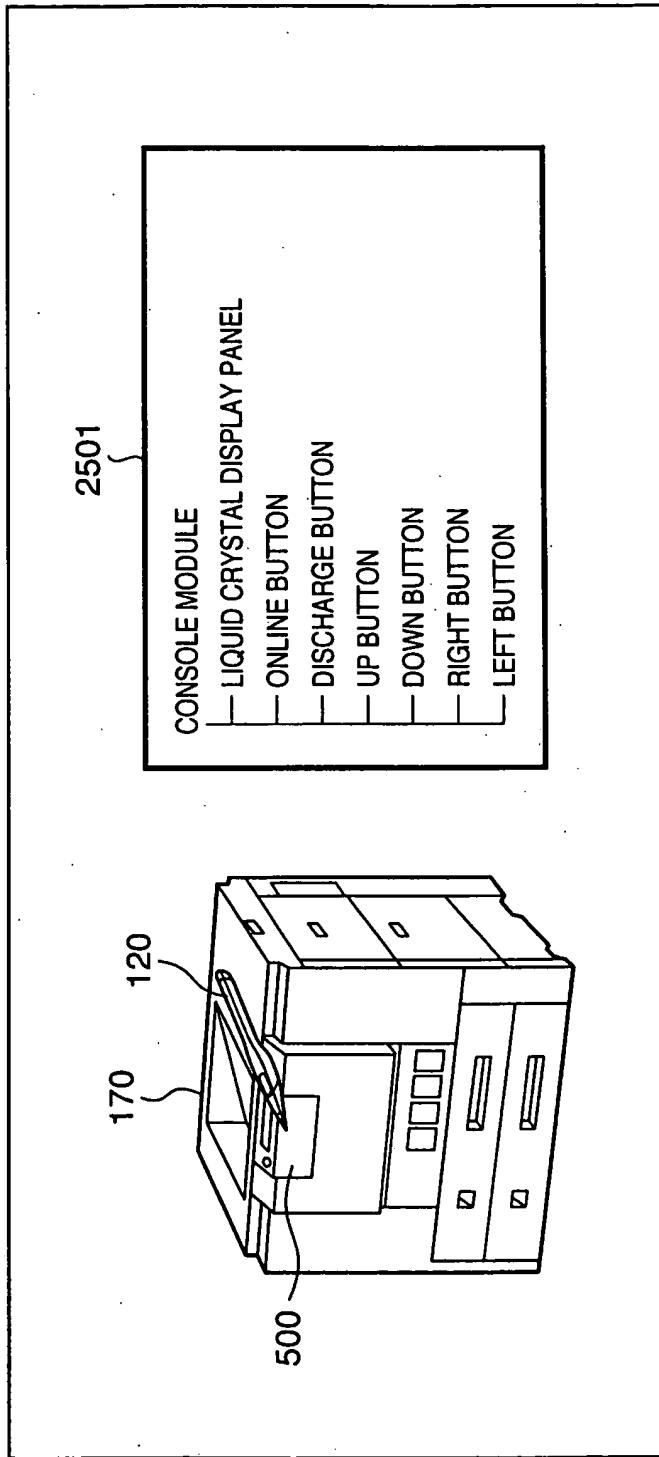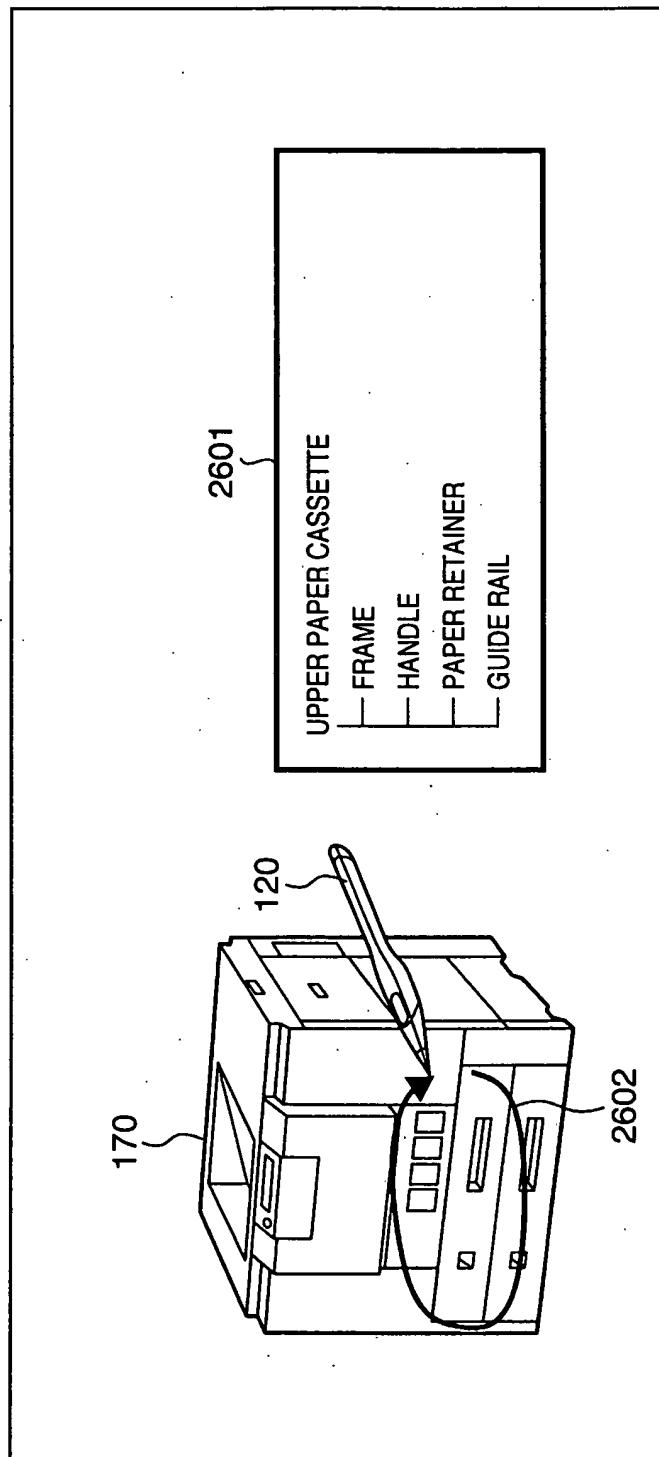
120

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F I G. 25

2501

CONSOLE MODULE
— LIQUID CRYSTAL DISPLAY PANEL
— ONLINE BUTTON
— DISCHARGE BUTTON
— UP BUTTON
— DOWN BUTTON
— RIGHT BUTTON
— LEFT BUTTON

120

170

500

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FIG. 26

2601

UPPER PAPER CASSETTE

├─ FRAME
├─ HANDLE
├─ PAPER RETAINER
└─ GUIDE RAIL

120

170

2602

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FIG. 27

PRINTER X
├ CONSOLE MODULE
├ RIGHT SIDE PANEL
├ UPPER PAPER CASSETTE
├ LOWER PAPER CASSETTE
└ PAPER DISCHARGE TRAY

120

2711

2701

170

2712

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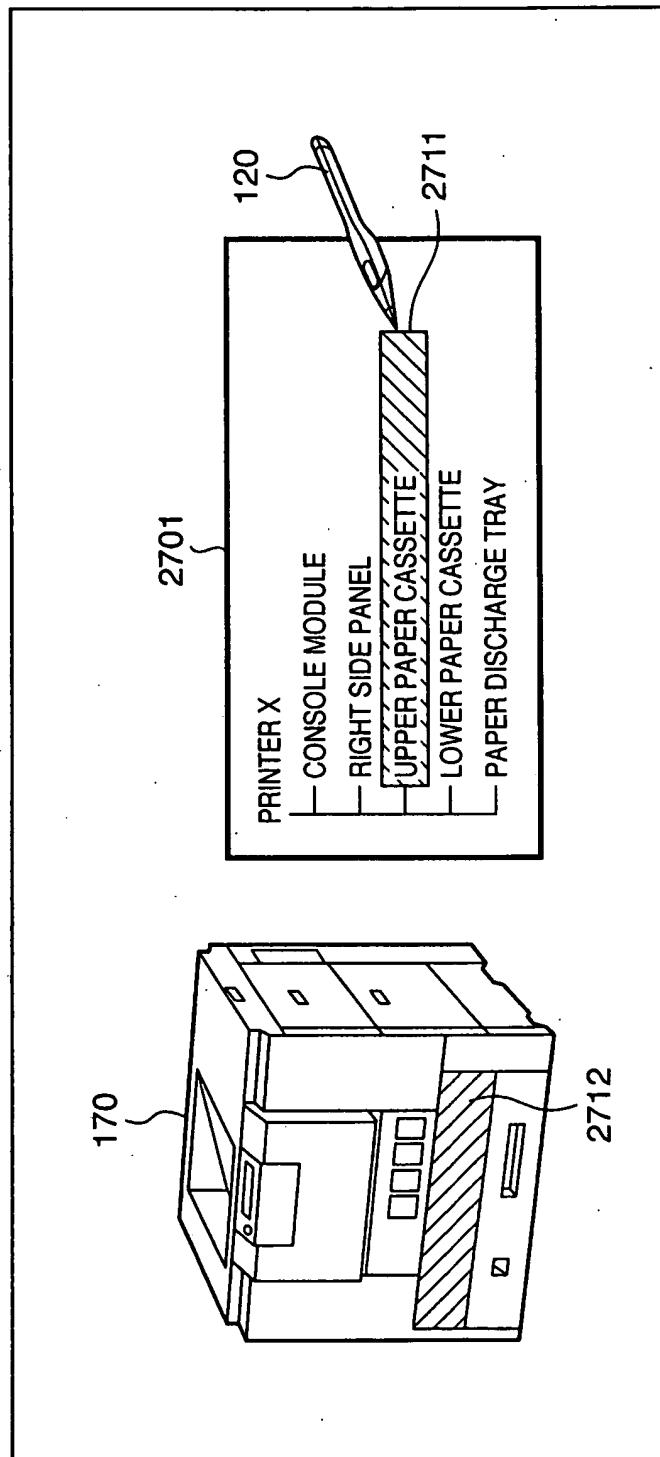30 ROCKEFELLER PLAZA
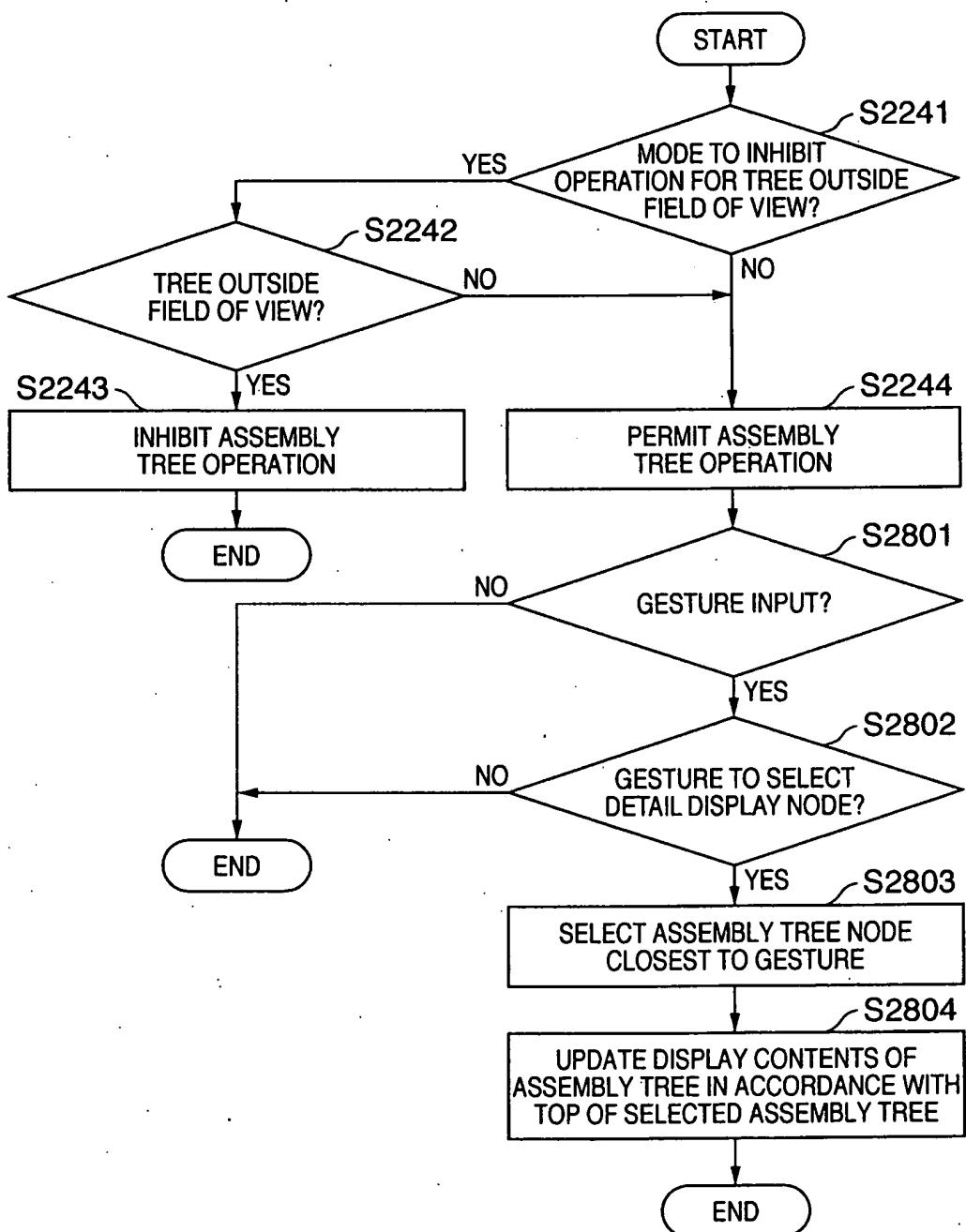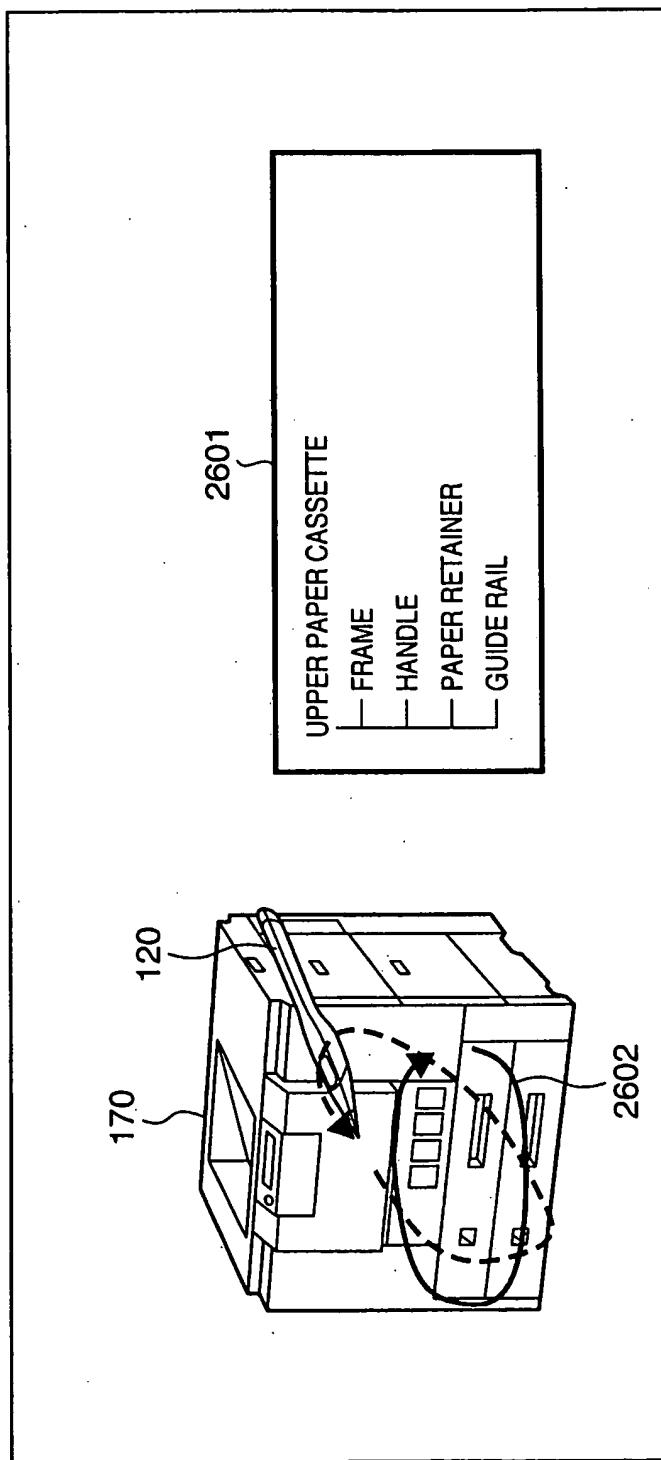NEW YORK, NEW YORK 10112
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F I G. 28

FIG. 29

2601

UPPER PAPER CASSETTE
— FRAME
— HANDLE
— PAPER RETAINER
— GUIDE RAIL

120

170

2602

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FIG. 30

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